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## THE ENDOSPERM IN SCROPHULARIACEAE

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THE study of the development of endosperm in the family Scrophulariaceae dates from the year 1849 when Tulasne made his classical observations. Since then a large number of workers (Hofmeister, 1859; Balicka-Iwanowska, 1899; Schmid, 1906; Glisic, 1932, 1933; Srinath, 1934, 1940; Krishna Iyengar, 1937, 1939-42; Raghavan and his co-workers, 1940, 1941, 1946; Crété, 1948-50, 1952-54, 1958; Yamazaki, 1953, 1954, 1957) have also contributed much to our knowledge of the endosperm in Scrophulariaceae. Samuelsson's work in 1913 followed by those of Schnarf (1929, 1931), Glisic (1936-37), Krishna Iyengar (1947) and Crété (1951, 1955) have thrown much light on the nature of the endosperm and its haustorial processes and have also indicated phylogenetic relationships between the different genera of Scrophulariaceae. Recently, Yamazaki (1953, 1954, 1957) working extensively on several genera of Scrophulariaceae has established phylogenetic relationships and affinities in the different genera on the basis of morphological and embryological characters.

The present account is a review of the notable work done till 1958 particularly on the endosperm and endosperm-haustoria of Scrophulariaceae and incorporates the unpublished work carried out in the Botanical Laboratory, Calcutta University, by Dr. N. Pal. An attempt has been made on the basis of his observations and the data obtained from previous workers to show clearly the phylogenetic relationships of the different genera.

(1) *Endosperm and Endosperm-haustoria*.—The formation of a cellular type of endosperm is characteristic of the family Scrophulariaceae. The only deviation is that recorded by Evans (1919) in *Pentstemon secundiflorus* which has later been severely criticised by Dahlgren (1923). Schmid (1906), however, recorded the occurrence of free-nuclear endosperm in a single instance in *Pedicularis foliosa*.

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The first division of the endosperm in all the plants so far investigated is transverse leading to the formation of a micropylar and a chalazal chamber. The next division, which occurs in the micropylar chamber, is vertical excepting in *Pedicularis*, *Melampyrum*, *Euphrasia* and *Tozzia* (Hofmeister, 1859; Schacht, 1863; Schmid, 1906; Lundquist, 1915; Krishna Iyengar, 1942 c) and in some other members of the family such as *Alonsoa*, *Sopubia*, *Vandellia*, *Bonnaya* and *Ilysanthes* (Krishna Iyengar, 1937, 1940 a, b and c). In *Angelonia* (Srinivasan, 1940) and *Nemesia* (Crété, 1950 a and b), however, the sequence is altogether different. In the former, all the early endospermic divisions are said to be transverse and in the latter, the micropylar chamber precociously differentiates into an uninucleate haustorium instead of undergoing any further division.

The chalazal chamber formed by the first division of the primary endosperm nucleus gives rise to the chalazal endosperm-haustorium quite early in the developmental history of the endosperm tissue, with the exceptions of *Nemesia* (Crété, 1950 a and b), *Ellisiophyllum* (Yamazaki, 1957 a) and in *Pedicularis*, etc. (Schmid, 1906; Krishna Iyengar, 1942 c). Srinivasan's (1940) account on the non-occurrence of endosperm-haustorium in *Angelonia grandiflora* has been questioned by Maheshwari and Navalakha (1941). Later, Krishna Iyengar (1947) doubted the validity of such observations in *Angelonia grandiflora* and stated that the haustoria are formed at both ends of the endosperm tissue. It may be mentioned here that in *Nemesia* (Crété, 1950 a and b) and *Ellisiophyllum* (Yamazaki, 1957 a), this chalazal chamber does not differentiate directly as the haustorial cell but undergoes further divisions to give rise to the endosperm tissue, while the micropylar chamber is precociously transformed into the haustorium.

The structure of the chalazal haustorium is very variable in different species of the family which ranges from a single uninucleate, or binucleate or tetranucleate cell, to two or four uninucleate juxtaposed cells. In *Gratiola* (Glisic, 1933; Yamazaki, 1953 b), these cells, however, are superposed. The haustorium is also not equally aggressive in the different members of the family. In *Lindenbergia indica* (Pal, 1958) the haustorium is composed of a uninucleate cell while in *Mazus japonicus* (Pal, 1958) there are two such cells which are later converted into a two-nucleate cell by the dissolution of the common vertical wall between them. It may be mentioned here that in *Mazus rugosus* (Hofmeister, 1859), this haustorium is very large, and prominent at maturity while in *Mazus japonicus* it is not so. One-celled uninucleate chalazal haustorium has also been observed in *Torenia* (Balicka-Iwanowska, 1899; Krishna Iyengar, 1941; Guilford and Fisk, 1952), *Limosella* (Samuelsson, 1913; Schnarf, 1925; Svensson, 1928), *Lathraea* (Glisic, 1932), *Limnophila* (Krishna Iyengar, 1939 b); *Moniera*, *Bacopa* (Safeeulla and Govindu, 1949 and 1950); *Glossostigma* (Safeeulla, 1950), *Alonsoa* (Crété, 1950 c); *Vandellia* and *Bonnaya* (Yamazaki, 1954 b). The occurrence of a chalazal haustorium consisting of two uninucleate cells which later become a 2-nucleate cell, as in *Mazus*



*japonicus*, has also been found in *Alonsoa*, *Sopubia*, *Bonnaya* and *Vandellia* (Krishna Iyengar, 1937, 1940 *a, b, c*; Srinivasan, 1940).

The micropylar endosperm-haustorium also seems to be of universal occurrence in the family which differentiates by the second transverse division (occurring in the micropylar chamber) of the growing endosperm tissue, exceptions having been noted in *Pedicularis*, *Nemesia* and *Ellisiophyllum* (Schmid, 1906; Krishna Iyengar, 1942 *c*; Crété, 1950 *a* and *b*; Yamazaki, 1957 *a*) where the micropylar haustorium differentiates precociously. The micropylar endosperm-haustorium, as in the case of chalazal, differs widely in its structure as well as in the degree of aggressiveness in different species of the family. In *Lindenbergia indica* (Pal, 1958), the single vertical wall of this haustorium is developed partially, only to disappear very soon. This type of micropylar haustorium seems to have been derived from *Veronica* or *Alectrolophus* series of Glisic (1936-37). Moreover, the haustorium in *Lindenbergia* shows less activity which possibly indicates a condition of primitiveness. In *Mazus japonicus* (Pal, 1958), the micropylar endosperm-haustorium consists of two uninucleate cells which are later transformed into a binucleate one. Similar behaviour has also been recorded in *Veronica* (Glisic, 1936-37; Yamazaki, 1957 *b*) and *Rehmannia* (Krishna Iyengar, 1942 *a*). Further, in *Mazus japonicus*, one or two tubular outgrowths protrude out from this haustorium. These processes penetrate inside the integumental tissue and proceed towards the chalaza. Such lateral proliferations of this haustorium were previously reported in *Alonsoa* (Krishna Iyengar, 1937; Crété, 1950 *c*); *Vandellia* (Krishna Iyengar, 1940 *a*); *Lyperia* (Crété, 1949); *Striga* (Tiagi, 1956) and in many other species of the family. In *Mazus rugosus*, Hofmeister (1859) demonstrated several such branches coming out from the micropylar endosperm-haustorium which seem to be very different in appearance from that observed by Pal (1958).

*Lindenbergia* and *Mazus* (Pal, 1958) are both characterised by successive transverse divisions of the two cells of the middle tier in the three-tiered endosperm (including haustoria) leading to the formation of a long narrow biseriate endosperm tissue apart from the two terminal endosperm-haustoria (vertical walls appear later in the lower cells, i.e., the cells situated towards the chalazal end producing a massive endosperm tissue). Similar development of biseriate endosperm tissue at the initial stages of growth has already been described in *Striga euphrasioides* (Srinivasan, 1946) and *Gratiola japonica* (Yamazaki, 1953 *b*). It also appears to be identical with *Angelonia grandiflora* (Srinivasan, 1940).

The formation of a group of small cells, rich in cytoplasm, by the endosperm tissue at one or both ends (i.e., chalazal and micropylar) just below the haustoria has been recorded in many members of the family (Michell, 1915; Glisic, 1933; Souéges, 1935; Krishna Iyengar, 1937, 1939 *a* and *b*, 1940 *a-c*, 1941, 1942 *a-c*; Srinath, 1940; Guilford and Fisk, 1952; Crété, 1953; Yamazaki, 1953 *b*, 1954 *b*, 1957 *b* and Tiagi, 1956). Balicka-Iwanowska's (1899) 'Secondary haustorium'



in *Linaria cymbalaria* and Berg's (1954) 'Cutis forming cells' in *Pedicularis silvatica* are also possibly identical in nature. In *Lindenbergia indica* (Pal, 1958), these cells are absent at the chalazal end. At the micropylar end of this plant, as well as in *Mazus japonicus*, the endosperm cells become specialised.

In *Mazus japonicus* (Pal, 1958), two uninucleate cells (which later become a single binucleate cell) of the chalazal haustorium degenerate very early and seem to be replaced by a second one, having originated secondarily from the lowermost tier of the endosperm tissue. Further, this structure becomes complicated by the addition of many new and small cell elements from the endosperm tissue. The ultimate amoeboid structure seems to form a modified type of chalazal conductive tissue of the endosperm which lasts for a considerable length of time in the developmental history of the seed. It may be mentioned here that Srinivasan (1946) considered the densely staining group of cells at the chalazal end in *Striga* as the secondary chalazal haustorium. Tiagi (1956), working with the same genus, differed from him and suggested that the function of these cells are only conductive in nature. It should be noted that the origin and structure of this tissue in *M. japonicus* are more or less different from any other species so far investigated in the family.

It may thus be said that in *M. japonicus* and *L. indica* (Pal, 1958), though the sequence of cell divisions in the endosperm is more or less identical, yet the behaviour of the tiers of cells is very different, which may be apparent from Figure 1.

(2) *Evolutionary tendencies in the development of endosperm-haustoria in the family Scrophulariaceae.*—Samuelsson (1913) and Schnarf (1929, 1931) have classified the different types of endosperm development in the members of this family. Later, Srinath (1940) discussed the origin and interrelationships in them. Glisic (1936–37), however, for the first time, produced an elaborate account on the trends of evolution of endosperm-haustoria in this family, which has later been enriched by the work of Krishna Iyengar (1947). Still later, Cr  t   (1951, 1955) and Pal (1958) modified the diagrammatic chart of Glisic and also attempted to find out the interrelationships of the family with the allied ones. On the other hand, Yamazaki (1953, 1954, 1957) tried to correlate the morphological and embryological data in several genera of the family. It may be useful here to discuss some of the available evidences regarding the evolutionary trends in the development of endosperm-haustoria in the family Scrophulariaceae.

The lines of evolution (as indicated here) are based mainly on the characteristic features of endosperm formation which have been followed by the previous authors. The multicellular (uninucleate cells) nature of the endosperm-haustoria has been considered as a primitive character, other characteristics being (1) sequence of early divisions in endosperm, (2) occurrence and behaviour of the partition walls (if any) in the haustoria, (3) number of cell or cells and/or nuclei in the



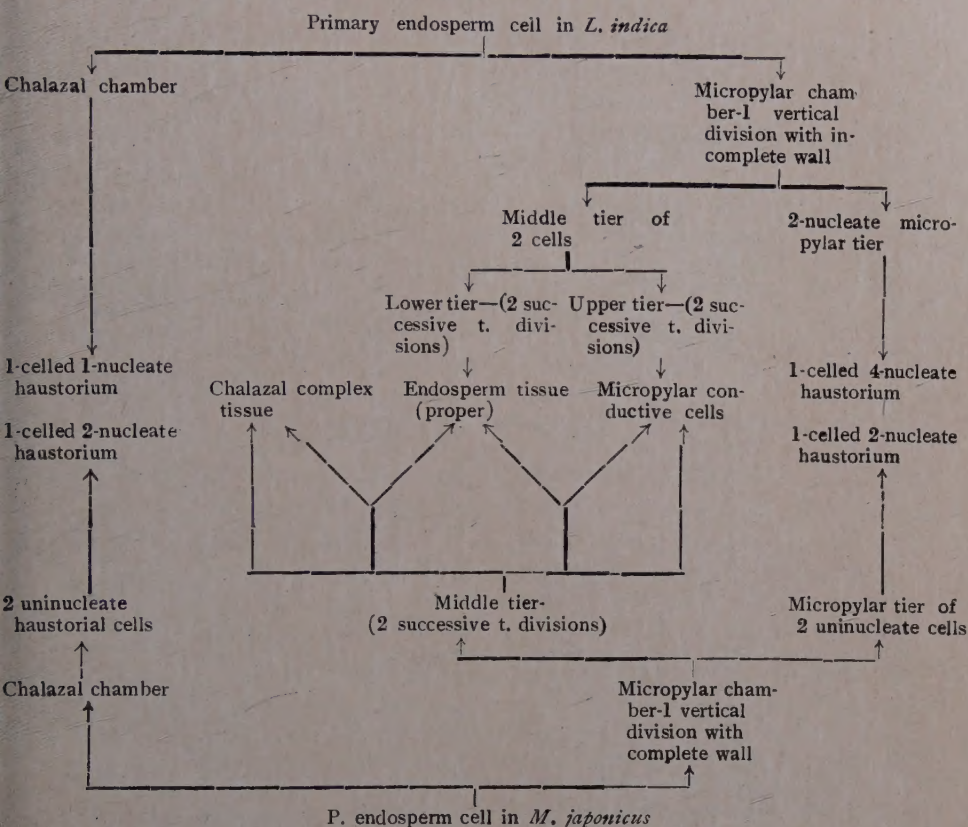


FIG. 1

haustoria and (4) plane of wall formation (if multicellular) in the haustoria.

Glisic's (1936-37) chart indicates three major lines of evolution of endosperm formation in the family. However, difficulties are encountered in accepting his proposal. First, he had to assume some hypothetical types like 'Pro-Veronica', 'Pro-Limosella' (this was probably unavoidable due to the lack of sufficient information available at his time) in his system. Secondly, the type, where the chalazal chamber (haustorium) of the endosperm undergoes a division with the formation of a vertical wall, and the type where the said division is not associated with wall formation, was considered by him to represent parallel lines of evolution and not as a derivative of the former type. Moreover, he could not assign a proper place for 'Pedicularis type' in his chart. It should be mentioned here that though in all the three lines of evolution in Glisic's chart, the division in the micropylar chamber of the endosperm (i.e., the second division of the endosperm) is vertical but in *Pedicularis*, *Melampyrum*, *Euphrasia* and *Tozzia* (Schmid, 1906;



Krishna Iyengar, 1942 c), the second division in the endosperm was found to be transverse in the chalazal chamber. Krishna Iyengar (1947) has, however, attempted to fill this gap by introducing a 'fourth line' in the evolutionary sequence where in the second cell generation, all the three cells of the endosperm lie in one row, the said division in the micropylar chamber (?) being transverse. The position of the 'Pedicularis type' has also been indicated by some of his observations on several species of the family, viz., species of *Alonsoa*, *Ilysanthes*, *Bonnaya*, *Sopubia*, *Vandellia* (Krishna Iyengar, 1937, 1940 a-c) where the said transverse division occurs in the 'micropylar chamber'. Similar sequence has also been noted in species of *Striga* (Michell, 1915) as well as in *Pedicularis* (Lundquist, 1915). Later, Crété (1951) cited two examples of the occurrence of both longitudinal or transverse divisions in the micropylar chamber in the same species and expressed his doubt on the systematic value of such variations. Further, he referred to the observations on some species of *Euphrasia* (Wurdinger, 1910) and *Veronica* (Weiss, 1932) where the sequence is similar to *Pedicularis*.

But in spite of all these evidences, the position of 'Pedicularis type' is yet open to question. The following points need consideration in this connection: (1) the most important contribution on this type (Schmid, 1906) lacks illustrations representing the successive stages; (2) most of the observations (Hofmeister, 1859; Schacht, 1863; Schmid, 1906; Lundquist, 1915; Michell, 1915) on this type (except those of Krishna Iyengar, 1937, 1940 a-c and 1942 c) are records of earlier investigations on the family; (3) in the majority of cases the division of the micropylar chamber in the members of this family is vertical and not transverse; and (4) a number of genera and species in which such observations have been made (i.e., occurrence of transverse division in the micropylar or chalazal chamber), also present examples of the types where this division is longitudinal such as *Veronica* (Gscheidle, 1924; Wiess, 1932; Yamazaki, 1957 b) and as classified by Glisic, 1936-37), *Alonsoa* (Crété, 1950 c), *Ilysanthes* (Raghavan and Srinivasan, 1941 a; Yamazaki, 1954 b), *Vandellia* (Srinivasan, 1940; Yamazaki, 1954 b) and *Striga* (Srinivasan, 1946; Tiagi, 1956). Moreover, Schmid's (1906) and Krishna Iyengar's (1942 c) descriptions on *Pedicularis* do not tally with other observations on the genus (Lundquist, 1915), as they state that the micropylar haustorium, instead of the chalazal one, is differentiated by the first division of the primary endosperm cell and further wall formation takes place only in the chalazal chamber, and thus the chalazal haustorium originates at a later stage of development. This sequence seems to be unnatural in this family though, the same has been substantiated later by the observations of Crété (1950 a and b) in *Nemesia* where the chalazal haustorium does not develop at all.

Recent observations of Berg (1954) on *Pedicularis silvatica* seems to invalidate the conception of 'Pedicularis type' of endosperm formation. He clearly demonstrated the formation of a vertical wall in the micropylar chamber of this species and suggested that Schmid's







interpretations were possibly erroneous due to several reasons as has already been admitted by himself (Schmid, 1906). It should be mentioned here that Glisic (1936-37) also expressed his doubts on the validity of such a type of development of endosperm as described previously in *Pedicularis*.

Glisic's (1936-37) 'Pro-Limosella type' has, however, been substantiated later by the observations of Crété (1948) and Yamazaki (1954 *b*) on *Chaenostoma*, *Ilysanthes* and *Lindernia*. 'Pro-Veronica type,' on the other hand, has been demonstrated in *Wulfenia carinthiaca* (Yamazaki, 1957 *a*).

Figure 2 gives a diagrammatic representation of the probable evolutionary sequence of the endosperm types in the family. It should, however, be mentioned that the diagram is a modified representation based on the works of Glisic, Krishna Iyenger and Crété. Further, in plants where the sequence has not been definitely established or where the division of the micropylar chamber has been found to be transverse or where the organisation of the embryo-sac does not follow the general scheme, have not been considered.

The chart is self-explanatory and no elaboration is necessary. The arrows indicate the sequence of development. The broken lines with arrows denote the probable lines of evolution of the different derivative types. The hypothetical "Pro-Pedicularis type" introduced here is the intermediate stage of Gratiola I type in Glisic's system and is yet to be demonstrated in the family. The dotted lines in the diagrams indicate the position of walls which in course of time have become obliterated.

#### REFERENCES

- BALICKA-IWANOWSKA, G. 1899. Contribution à l'étude du sac embryonnaire chez certaines Gamopétales. *Flora, Jena*. **86**: 47-71.
- BERG, R. Y. 1954. Development and dispersal of the seed of *Pedicularis silvatica* *Nytt Mag. Bot.* **2**: 1-60.
- CRÉTÉ, P. 1948. Recherches embryologiques chez les Scrofulariacées, Développement de l'albumen et de l'embryon chez le *Chaenostoma foetidum* (Jacq.) Benth. *Bull. Soc. bot. Fr.* **95**: 142-46.
- . 1949. Recherches embryologiques chez les Scrofulariacées. Développement de l'albumen chez le *Lyperia violacea* Benth. *Ibid.* **96**: 186-88.
- . 1950 *a*. Embryologie des Scrofulariacées. Développement de l'albumen chez les *Nemesia*. *C.R. Acad. Sci. Paris* **231**: 711-13.
- . 1950 *b*. Embryologie des Scrofulariacées. L'albumen et l'embryon chez les *Nemesia*. *Bull. Soc. bot. Fr.* **97**: 196-97.
- . 1950 *c*. Embryologie des Scrofulariacées. Développement de l'albumen chez l'*Alonsoa caulaulata* Ruiz. et Pav. *Ibid.* **97**: 177-79.
- . 1951. Répartition et intérêt phylogénétique des albumens a Formations haustoriales chez les Angiospermes et plus particulièrement chez les Gamopétales. *Ann. Sci. nat. Bot. Ser.* **12**: 131-91.



- . 1952. Embryologie des Scrophulariacées. Développement de l'albumen et de l'embryon chez le *Teedia lucida* (Soland.) Rud. *Bull. Soc. bot. Fr.* 99: 266-68.
- . 1953. Embryologie des Scrophulariacées. Développement de l'albumen et de l'embryon chez le *Digitalis purpurea* L. *Phytomorphology* 3: 168-72.
- . 1954 a. Le développement de l'albumen et de l'embryon chez le *Tetranema mexicanum* Benth. *Bull. Soc. bot. Fr.* 101: 232-35.
- . 1954 b. Embryologie de l'*Erinus alpinus* L. (Scrophulariacées). Les relations entre les genres *Erinus* L. et *Digitalis* L. *Phytomorphology* 4: 325-28.
- . 1955. L'Application de certaines données embryologiques à la systématique des Orobanchacées et de quelques familles voisines. *Ibid.* 5: 422-35.
- . 1958. Développement de l'albumen et l'embryon chez le *Collinsia bicolor* Benth. *Ibid.* 8: 302-05.
- DAHLGREN, K. V. O. 1923. Notes on the *ab initio* cellular endosperm. *Bot. Notiser* 1923: 1-24.
- EVANS, A. T. 1919. Embryo-sac and embryo of *Pentstemon secundiflorus*. *Bot. Gaz.* 67: 426-37.
- GLISIC, LJ. M. 1932. Zur Entwicklungsgeschichte von *Lathraea squamaria* L. *Bull. Inst. bot. Univ. Belgrade* 2: 20-56.
- . 1933. Zur Entwicklungsgeschichte von *Gratiola officinalis* L. *Ibid.* 2: 129-52.
- . 1936-37. Ein Versuch der Verwertung der Endospermmerkmale für typologische und phylogenetische Zwecke innerhalb der Scrophulariaceen. *Ibid.* 4: 42-73.
- GSCHIEDLE, A. 1924. Über Haustorienbildung in der Gattung *Veronica*. *Flora, Jena* 117: 144-72.
- GUILFORD, V. B. AND FISK, E. L. 1952. Megasporogenesis and seed development in *Mimulus trigrinus* and *Torenia fournieri*. *Bull. Torrey bot. Cl.* 79: 6-24.
- HOFMEISTER, W. 1859. Neue Beiträge zur Kenntnis der Embryobildung der Phanerogamen. *Abh. sachs. Ges. (Akad.) Wiss.* 6: 535-672.
- KRISHNA IYENGAR, C. V. 1937. Development of the embryo-sac and endosperm-haustoria in some members of Scrophularineae. I. *Sopubia delphinifolia* G. Don. and *Alonsoa* sp. *J. Indian bot. Soc.* 16: 99-109.
- . 1939 a. Development of embryo-sac and endosperm haustoria in some members of Scrophularineae. II. *Isoplexis canariensis* Lindl. and *Celsia coromandeliana* Vahl. *Ibid.* 18: 13-20.
- . 1939 b. Development of embryo-sac and endosperm haustoria in some members of Scrophularineae. III. *Limnophila heterophylla* Benth. and *Stemodia viscosa* Roxb. *Ibid.* 18: 35-42.
- . 1940 a. Development of embryo-sac and endosperm haustoria in some members of Scrophularineae. IV. *Vandellia hirsuta* Ham. and *V. scabra* Benth. *Ibid.* 19: 179-89.
- . 1940 b. Development of embryo-sac and endosperm haustoria in some members of Scrophularineae. V. *Ilysanthes hyssopioides* Benth. and *Bonnaya tenuifolia* Spreng. *Ibid.* 19: 5-17.
- . 1940 c. Structure and development of seed in *Sopubia trifida* Ham. *Ibid.* 19: 251-61.



- KRISHNA IYENGAR, C. V. 1941. Development of embryo-sac and endosperm haustoria in *Torenia cordifolia* Roxb. and *T. hirsuta* Benth. *Proc. nat. Inst. Sci. India* 7: 61-71.
- . 1942 a. Development of embryo-sac and endosperm haustoria in *Rehmannia angulata* Hemsl. *J. Indian bot. Soc.* 21: 51-57.
- . 1942 b. Development of embryo-sac and endosperm haustoria in *Tetranema mexicana* Benth. and *Verbascum thapsus* Linn. *Proc. nat. Inst. Sci. India* 8: 59-69.
- . 1942 c. Development of seed and its nutritional mechanism in Scrophulariaceae. Part I. *Rhambhica longiflora* Benth., *Centranthera hispida* Br. and *Pedicularis zeylanica* Benth. *Ibid.* 8: 249-61.
- . 1947. Development of seed and its nutritional mechanism in the Scrophulariaceae. Part II. *J. Mysore Univ.* 7 B: 82-98.
- LUNDQUIST, G. 1915. Die Embryosackentwicklung von *Pedicularis sceptrum-carolinum* L. *Z. Bot.* 7: 545-59.
- MAHESHWARI, P. AND NAVALAKHA, H. S. 1941. A note on the embryology of *Scoparia dulcis* Linn. and *Angelonia grandiflora* C. Moor. *Curr. Sci.* 10: 297-99.
- MICHELL, R. M. 1915. The embryo-sac and embryo of *Striga lutea*. *Bot. Gaz.* 59: 124-35.
- PAL, N. 1958. *D. Phil. Thesis*, Calcutta University.
- RAGHAVAN, T. S. AND SRINIVASAN, V. K. 1941 a. Morphological and cytological studies in the Scrophulariaceae. III. A contribution to the life-history of *Ilysanthes parviflora* Benth. *Proc. Indian Acad. Sci.* 13B: 24-32.
- . 1941 b. Morphological and cytological studies in the Scrophulariaceae. IV. The development of the embryo-sac and endosperm in *Scoparia dulcis* Linn. *Ibid.* 13B: 229-34.
- SAFEULLA, K. M. 1950. Development of the female gametophyte and endosperm in *Glossostigma spathulatum*. *Proc. Indian Sci. Congr.* Part III, 47.
- AND GOVINDU, H. C. 1949. The development of the female gametophyte and endosperm in *Moniera hamiltoniana* T. Cooke. *Ibid.* Part III, 129-30.
- AND ———. 1950. The development of the female gametophyte and endosperm in *Bacopa hamiltoniana*. *Lloydia* 13: 179-82.
- SAMUELSSON, G. 1913. Studien über die Entwicklungsgeschichte der Blüten einiger Bicornes-Typen. Ein Beiträge zur Kenntnis der systematischen Stellung der Diapensiaceen und Empetraceen. *Svensk bot. Tidskr.* 7: 97-188.
- SCHACHT, H. 1863. Über die Zellstoffäden in der vorderen Aussackung des Embryosackes von *Pedicularis silvatica*. *Jb. wiss. Bot.* 3: 339-51.
- SCHMID, E. 1906. Beiträge zur Entwicklungsgeschichte der Scrophulariaceen. *Beih. bot. Cbl.* 20 (1): 175-299.
- SCHNARF, K. 1925. Kleine Beiträge zur kenntnis der Entwicklungsgeschichte der Angiospermen. V. Über zwei kritische Fälle der Endospermentwicklung (*Verbena* und *Triglochin*). *Ost. bot. Z.* 74: 40-50.
- . 1929. *Die Embryologie der Angiospermen* in von K. Linsbauer; *Handb. d. Pflanzenanatomie*. Berl Gebr. Borntraeger. Abt. II. 2 Teil.
- . 1931. *Vergleichende Embryologie der Angiospermen*. Verlag von Gebrüder Borntraeger. Berlin. 177-80.
- SOUÈGES, R. 1935. Recherches embryogéniques sur les Verbasceés. Les types secondaires due développement embryonnaire. *Bull. Soc. bot. Fr.* 82: 328-34



- SRINATH, K. V. 1934. Life-history of *Herpestis monniera* H. B. and K. *Curr. Sci.* 3: 257-58.
- . 1940. Morphological studies in the genera *Calceolaria* and *Herpestis*. I. *Proc. Linn. Soc. Lond.* 2: 152-74.
- SRINIVASAN, A. R. 1946. Morphological and cytological studies in the Scrophulariaceae. V. *Striga euphrasioides* Benth. *Proc. Indian Acad. Sci.* 24 B: 21-33.
- SRINIVASAN, V. K. 1940. Morphological and cytological studies in the Scrophulariaceae. II. Floral morphology and embryology of *Angelonia grandiflora* C. Moor and related genera. *J. Indian bot. Soc.* 19: 197-222.
- SVENSSON, H. G. 1928. Zur Entwicklungsgeschichte der Blüten und Samen von *Limosella aquatica* L.. *Svensk bot. Tidskr.* 22: 465-76.
- TIAGI, B. 1956. A contribution to the embryology of *Striga orobanchoides* Benth. and *Striga euphrasioides* Benth. *Bull. Torrey bot. Cl.* 83: 154-70.
- TULASNE, L. R. 1849. Études d'embryogénie végétale. *Ann. Sci. nat. Bot. Ser. III.* 12: 21-137.
- WEISS, G. 1932. Weitere Beiträge zur Kenntnis der Endosperm-haustorien in der gattung *Veronica*. *Flora, Jena* 126: 418-69.
- WURDINGER, M. 1910. Bau und Entwicklungsgeschichte des Embryosackes von *Euphrasia Rostkoviana*. *Denkschr. Akad. Wiss. Wien* 85.
- YAMAZAKI, T. 1953 a. On the floral structure, seed development, and affinities of *Deinostema*, a new genus of Scrophulariaceae. I. *J. Jap. Bot.* 28: 129-33.
- . 1953 b. On the floral structure, seed development, and affinities of *Deinostema*, a new genus of Scrophulariaceae. II. *Bot. Mag. Tokyo* 66: 141-49.
- . 1954 a. Notes on *Lindernia*, *Vandellia*, *Torenia* and their allied genera in Eastern Asia. I. *J. Jap. Bot.* 29: 299-306.
- . 1954 b. Notes on *Lindernia*, *Vandellia*, *Torenia* and their allied genera in Eastern Asia. II. *Bot. Mag. Tokyo* 68: 14-24.
- . 1957 a. Seed formation of *Ellisiophyllum pinnatum* var. *reptans*. *Ibid.* 70: 162-68.
- . 1957 b. Taxonomical and phylogenetic studies of Scrophulariaceae—Veronicae with special reference to *Veronica* and *Veronicastrum* in Eastern Asia. *J. Fac. Sci. Univ. Tokyo, Sec. III.* 7(2): 91-162.



# VIRUS DISEASES OF PEPPER (*CAPSICUM* SPP.)

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## INTRODUCTION

PEPPERS (*Capsicum* spp.) are subject to a large number of virus diseases besides being susceptible to artificial infection by a number of viruses. However, no comprehensive account of the virus diseases of pepper is available. The author was prompted, therefore, to compile the information collected by him in the course of study of a virus disease of pepper, in the form of a review presented in the following pages.

In the present review the viruses affecting pepper are discussed under the following heads: 1. Viruses occurring naturally on pepper. 2. Viruses artificially transmitted to pepper. 3. Unidentified viruses. The viruses are designated both by their common name as given by Smith (1957) and their Latin binomial according to the system of Holmes (1948), where available.

### 1. *Viruses occurring naturally on pepper*

The following is a list of viruses causing natural diseases on pepper:

1. Cucumber mosaic virus.
2. Tobacco mosaic virus.
3. Tobacco etch virus.
4. Alfalfa mosaic virus.
5. Pepper vein-banding virus.
6. Potato virus Y.
7. Cranberry false-blossom virus.
8. Tomato spotted-wilt virus.

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9. Beet curly-top virus.
10. Tobacco leaf-curl virus.
11. Aster ringspot virus.
12. Trinidad pepper mosaic virus.
13. Indian chilli mosaic virus.
14. Puerto Rican pepper mosaic virus.
15. Trinidad pepper vein-banding virus.
16. Italian pepper mosaic virus.
17. Pepper yellow-leaf virus.

Of the above viruses 1-11 are listed in Holmes (1948) or Smith (1957). The rest of them (12-17) do not find a place in these manuals. However, a great deal of information including details of virus properties is available about all of them except the pepper yellow-leaf virus. Moreover, most of these viruses cause serious diseases on pepper in some countries and are therefore important factors in pepper production. It was felt therefore, that these also should find a place in a review of the present type. The characteristics of viruses naturally occurring on pepper are summarised in Table I.

## 2. *Viruses artificially transmitted to pepper*

The following is the list of viruses artificially transmitted to pepper. In many cases no detailed account of the symptomatology following inoculation is available; but where available, the information has been summarised.

1. Potato virus X.
2. Tomato bushy stunt virus.
3. Tomato ringspot virus.
4. Potato aucuba mosaic virus.
5. Potato leaf-roll virus.
6. Potato stunt virus.
7. Broad bean vascular wilt virus.
8. Carrot motley dwarf virus.
9. Sweet-potato mosaic virus.
10. Yam mosaic virus.
11. Sunflower mosaic virus.
12. Radish stunt virus.

TABLE  
Characteristics of

Virus	Dilution end point	Thermal inactivation point	Ageing <i>in vitro</i>	Sap transmissible or not
1 Cucumber mosaic virus <i>Strains of CMV</i>	..	..	..	Yes
(a) Ringspot strain	1 : 10,000	70-72° C.	4 days at 18° C.	"
(b) Southern celery mosaic strain	1 : 10,000	75° C.	6-8 days at room temperature	"
(c) Southern CMV	} 1 : 10,000 to 1 : 20,000	65-70° C.	..	"
(d) Pepper calico				
(e) Pepper oakleaf				
2 Tobacco mosaic virus <i>Strains of TMV</i>	..	..	..	"
(a) "Ring" strain	1 : 1,000,000	90° C.	..	"
(b) <i>Marmor tabaci</i> v. <i>siccans</i>	1 : 1,000,000	90-95° C.	7 years at 21-27° C.	"
(c) Tobacco paramosaic virus	Closely similar to TMV			"
(d) Tomato atypical mosaic virus	1 : 1,000,000	72° C.	..	"
(e) Tomato streak virus	Not known			"
(f) Seed-borne strain	1 : 1,000,000	85-90° C.	18 months in dried tobacco leaves	"
3 Tobacco etch virus	..	..	..	"
4 Alfalfa mosaic virus <i>Strains of AMV</i>	..	..	..	"
(a) Potato calico strain	..	53-55° C.	72-96 hrs. at 16° C.	"
(b) <i>Marmor medicaginis</i> v. <i>capsici</i>	..	63-64° C.	..	"
(c) <i>M. medicaginis</i> v. <i>ladino</i>	1 : 100	62-63° C.	48 hrs. at 18-20° C. 60 min. at 28° C.	"
5 Pepper vein-banding mosaic virus	1 : 20,000	60-65° C.	10-15 days at 23° C.	"
6 Potato virus Y	..	..	..	"
7 Cranberry false blossom virus	..	..	..	No
8 Tomato spotted-wilt virus	..	..	..	..
9 Beet curly-top virus	..	..	..	..
10 Tobacco leaf curl virus	..	..	..	..
11 Aster ringspot virus	..	75-80° C.	..	Yes
12 Trinidad pepper mosaic virus	1 : 5,000	63° C.	16 days at 15° C.	"
13 Indian chilli mosaic virus	1 : 25,000 to 1 : 30,000	55-60° C.	15-22 days at room temperature	"
14 Puerto Rican pepper mosaic virus	1 : 100	55-58° C.	48 hrs. at 22° C.	"
15 Trinidad pepper vein-banding virus	1 : 2,000,000	62° C.	6 days at 25-30° C.	"
16 Italian pepper mosaic virus	No information available	..	..	..
17 Pepper yellow leaf virus	"	..	..	..



## Pepper Viruses

Insect vector	Other methods of transmission	Naturally occurring pepper viruses—Distribution	References
<i>Myzus persicae</i> , <i>Doralis frangulae</i> Not known <i>Myzus persicae</i>		Bulgaria, Hungary, Italy, Portugal, Spain, U.S.A., Yugoslavia	Doolittle & Walker, 1923, 1925; Doolittle & Laumbyer, 1952, 1953; Kovachevsky, 1940, 1942; Szirmai, 1937/40, 1948; Bennloch & Dominiguez, 1934; Wellman, 1934; A. Simons, 1957; and D'Oliveira, 1940
<i>Aphis gossypii</i> , <i>Myzus persicae</i> , <i>Aphis rumicis</i>			
None		Bulgaria, Ceylon, Czechoslovakia, Germany, Japan, New Zealand, U.S.A., South America, Spain, Trinidad	Anderson, 1957; Anderson & Corbett, 1957; Kendrick, <i>et al.</i> , 1951; Panjam & Prpic, 1955; Zabala & D'Costa, 1947; Brien, 1942; Chamberlain, 1947; Dale, 1943; D'Oliveira, 1940; Newton, 1953; Peiris, 1953; Kovachevsky, 1942; Doolittle & Beecher, 1942; Nakata & Takimoto, 1940; Kholer & Panjan, 1943; Miller & Thornberry, 1958; Ainsworth, 1933; Chamberlain, 1947; McKinney, 1952
"	By seeds		Greenleaf, 1953, 1956; Anderson & Corbett, 1957; McKeen, 1953, 1954; Cook & Anderson, 1959
"			Kovachevsky, 1942; Porter, 1935; Sutic, 1959; Oswald, 1950; Berkely, 1947, 1947 A; Krietlow & Price, 1949
<i>Myzus persicae</i>		U.S.A., Canada	
"		Bulgaria, Canada, Germany, U.S.A., Yugoslavia	
"	By seed also		
"			
<i>Myzus persicae</i> , <i>Aphis gossypii</i> <i>Myzus persicae</i>		U.S.A.	Simons, 1956, 1957
"		Bulgaria, U.S.A.	Kovachevsky, 1942; Anderson, 1956; Anderson & Corbett, 1957; Simons, 1959; Sakimura, 1953; Cook & Anderson, 1959; David & Stormer, 1941; Bohme, 1933
"		Austria, Bulgaria, Russia	Wenzel, 1956; Sukhov & Voik, 1946, 1947; Feiginsan, 1936; Blattny, <i>et al.</i> , 1954
<i>Frankliniella paucispinosa</i>		Mexico, Netherlands, U.S.A.	Smith, 1932, 1936; Van Schreven, 1935; Ploper, 1948; Chupp, 1937; Gardner & Whipple, 1934; Gardner <i>et al.</i> , 1937; Pirone, 1935; Kendrick <i>et al.</i> , 1951
"		U.S.A.	Severin, 1929; Dana, 1934; Leyendeker, 1950; Menzies & Giddings, 1953
<i>Bemisia inconspicua</i>		India, Ceylon, Spain	Sardina, 1940; Peiris, 1957; Husain, 1932; Vasudeva, 1954
"		U.S.A.	Anderson, 1954; Swank, 1952
"		Trinidad	Ferguson, 1951
<i>Aphis gossypii</i> , <i>Myzus persicae</i> , <i>Aphis evonymi</i>		Indian, Pakistan	MacRae, 1924; Kulkarni, 1924; Uppal, 1929; Vasudeva, 1954; Jha & Raychoudhuri, 1956; Nariani & Sastry, 1958
"		Puerto Rico	Cook, 1929, 1930; Roque & Adsuar, 1939, 1941; Perez & Adsuar, 1955
<i>Aphis gossypii</i>		Trinidad, U.S.A.	Dale, 1954, 1956
"	<i>Cuscuta pentagona</i>	Italy, Spain	Ajroldi, 1939; Gualaccini, 1956; Bennloch & Dominguez, 1934
"		U.S.A.	Heuberger, 1944

13. Trinidad tomato twisted-leaf virus.
14. Trinidad tomato bronze-leaf virus.
15. Trinidad eggplant mosaic virus.
16. Tomato necrosis virus.
17. Tomato yellow mosaic virus.

#### VIRUSES OCCURRING NATURALLY ON PEPPER

##### 1. *Cucumber mosaic virus* (*Marmor cucumeris* Holmes)

As early as 1921 Doolittle showed that the cucumber mosaic virus could infect pepper plants. Further evidence of this was furnished by Doolittle and Walker (1923, 1925) who also described the symptoms of natural infection on pepper. They observed that the younger leaves of infected plants curled downwards along the midrib and that the basal portion of the leaf was frequently of a lighter green colour than that at the top. Within a short time these leaves developed a mottled appearance. Only the very young leaves and those produced after infection were affected this way. The leaves were reduced in size and the stem internodes were shortened. The plants had, therefore, a compact habit. The leaves were also drawn out in filiform fashion and were abnormally narrow. In a few cases the fruits of diseased pepper showed warty, dark green outgrowths which were comparable to those found on fruits of mosaic-affected cucumber.

A full description of a disease of pepper called "Reisigkrankheit" or "Rosette disease" occurring in Bulgaria has been given by Kovachevsky (1940, 1942). A 100% infection was not uncommon and in such cases the yield was reduced to 10–30% of normal. The symptoms of the disease as described by Kovachevsky were essentially similar to those given by Doolittle and Walker (1925). Kovachevsky, however, observed certain additional symptoms. These were, a distortion of the leaves which became asymmetrical and the appearance of necrotic patches on the stems of affected plants. On young stems these appeared as more or less elongated, linearly arranged pustules, while on the older stems the necrosis was superficial and corky. The fruit-setting was sharply reduced, the few that were set being badly deformed. These deformed fruits showed necrotic streaks.

A disease of pepper in Hungary described as "Ujhítuseg" by Szirmai (1937/1940, 1948) is considered by Kovachevsky (1942) to be the same as the "Rosette" disease in Bulgaria. A disease known as "niebla nueva" in Spain (Bennloch and Dominguez, 1934) and the disease known as "arriciamento" in Italy and "Kustistost" in Russia have similar symptoms to the rosette disease and are probably caused by the cucumber mosaic virus (Kovachevsky, 1940).

##### *Strains of cucumber mosaic virus*

1. *Ringspot strain*.—Doolittle and Zaumeyer (1952, 1953) described a ringspot disease of pepper caused by a strain of cucumber



mosaic virus. The disease was found to occur naturally in the states of New Jersey, Maryland and Delaware of the United States of America. The disease was characterised by large chlorotic rings and oakleaf patterns on older leaves and concentric yellow rings on the fruits. The rings on the fruit later became necrotic and the consequent fruit-spotting caused appreciable damage. Pepper plants (varieties *California Wonder* and *World Beater*) inoculated with the virus at temperatures between 21 and 28° C. showed yellow green spots on inoculated leaves. These spots were 2 mm. in diameter and had darker margins and centres with concentric rings. The leaves were yellowed. On young plants the infected leaves soon dropped off, but on older plants they persisted for some time. Systemically infected leaves developed pale green, concentrically ringed spots, 2-3 mm. in diameter. These spots coalesced and produced an intricately mottled pattern. Within two to three weeks from infection some of the older leaves showed circular spots 6-8 mm. in diameter with pale green concentric markings. Such spots were soon surrounded by a broad band of yellow green with a diffuse margin. As the yellow band developed the concentric markings in the centre became very faint and the spots appeared as wide yellow rings. Usually only 1-3 spots appeared on a leaf. Some leaves were not ring-marked but developed pale green oakleaf patterns which eventually became necrotic and the leaves dropped. In late stages of the disease the leaves were faintly mottled with flecks of light green, were slightly misshapen and were more pointed than those of healthy plants. There was very little leaf malformation in early stages of the disease.

Young fruits of affected plants showed no evidence of disease although occasional ones had pale green blotches of irregular shape. As fruits approached the mature green stage some were marked with concentric ringspots 8-20 mm. in diameter, similar to those on leaves but without any yellow bands around them.

A closely related strain of cucumber mosaic virus isolated from alfalfa leaves produced a milder mottling on pepper and less ringspotting on older leaves. The strain was isolated from mottled alfalfa leaves received from Idaho.

2. *Southern celery mosaic strain of cucumber mosaic virus.*—In 1931 Doolittle showed that a virus attacking celery occurred naturally on *Commelina nudiflora* also. This virus experimentally infected pepper plants causing symptoms resembling those produced by cucumber mosaic virus. This virus was studied by Wellman (1934, 1934 A, 1935, 1935 A) under the name of Southern celery mosaic virus. He considered the virus to be new and called it Celery Virus 1. This virus was shown by Price (1935) to be a strain of cucumber mosaic virus on the basis of immunological studies on *Zinnia* and symptom picture on *Zea mays*, *Commelina communis* and *Vigna sinensis*.

This strain of cucumber mosaic virus is stated to occur naturally on *Capsicum annuum* in Cuba and Florida (Wellman, 1934 A). Pepper plants infected in the field generally appeared stunted. Leaves were

small and distorted but without filiformity, but with grayish dull colour markings. The plants appeared starved and blossoms dropped. If fruits had set before infection they became malformed. Leaves had a mild mottle coupled with a finely *moire* pattern.

Small seedlings of *Tabasco* pepper developed black primary lesions on leaves inoculated with the virus, in about 3–8 days. The infection became systemic, becoming noticeable as a twisting and crook-neck of the tender tip region. After a few days the crook straightened out. The plants remained alive but severely stunted with marked mottling symptoms on the systemically infected leaves. On the seedlings of the variety *California Wonder* light brown streaks appeared causing a severe dropping of leaves and death of seedlings. Many plants also had crook-neck symptoms. Very often flowers dropped or did not set fruit.

3. *Southern cucumber mosaic virus, pepper calico virus and pepper oakleaf virus*.—Simons (1957) described the above three viruses as affecting bell pepper in the Everglades area of South Florida. He showed that the three viruses were immunologically related and were probably strains of cucumber mosaic virus. The southern cucumber mosaic virus was the commonest and caused the most severe symptoms on pepper, while the other two were of sporadic occurrence. On pepper, southern cucumber mosaic virus caused vein clearing, local chlorosis, severe stunting and redspider like injury. The oakleaf virus caused vein clearing and necrotic oakleafing on senescent leaves while the calico virus caused a vein clearing, local chlorosis and calico mottle. Simons measured the titre of active southern cucumber mosaic virus in pepper using the single aphid feed method. The titre rose to a maximum in two weeks after inoculation and then fell sharply.

A 'yellow strain' of cucumber mosaic virus from gladiolus is reported to have been transferred to *California Wonder* pepper by Berkeley (1951).

#### *Transmission of cucumber mosaic virus and its strains and epidemiology.*

Doolittle and Walker (1923) reported the mechanical inoculation of pepper plants with the cucumber mosaic virus. They also found (Doolittle and Walker, 1925) that the cucumber aphid readily transmitted the virus to peppers in the field. There was no evidence of seed transmission. Kovachevsky (1940), however, could not obtain mechanical transmission, but the aphid *Myzus persicae* readily transmitted the disease. It is believed that in Bulgaria the disease is transmitted in the field by the vectors *Myzus persicae* and *Doralis frangulae* (= *Aphis gossypii*). D'Oliveira (1940) also reported that the disease rapidly spread in the field in Portugal by means of insects. He did not find any seed transmission.

The ringspot strain of cucumber mosaic virus was mechanically transmissible (Doolittle and Zaumeyer, 1953). It is not known how this virus spread in the field.



A study of the spread of the southern celery mosaic virus on squash, pepper and celery was carried out by Wellman (1935 A). *Commelina nudiflora* growing on the edge of the vegetable field was the principal weed host and *Myzus persicae*, the important vector. The disease appeared initially on the edge of the pepper field near an infected weed patch. After introduction into the field the disease spread inwardly but did not necessarily extend to make a fan-shaped pattern, nor was there a frontier border of spread progressing in an unbroken line as a wave would spread. Dissemination was evident as a successive development of small scattered areas which upon expansion coalesced and in turn resulted in further infection and widely dispersed centres of disease. This continued until the whole field was infected.

The three strains of cucumber mosaic virus reported by Simons (1957) were transmitted by *Aphis gossypii* and *Myzus persicae* and were non-persistent in these vectors. Simons (1955) also found that the southern cucumber mosaic virus was transmitted in descending order of efficiency by the three vectors *Aphis gossypii*, *Myzus persicae* and *Aphis rumicis*.

#### *Physical properties of cucumber mosaic virus and its strains reported on pepper*

No information is available on the physical properties of the typical strain of cucumber mosaic virus causing the mosaic or "rosette" disease of pepper. The ringspot strain reported by Doolittle and Zaumeyer (1952) had a thermal inactivation point of 70–72° C. and a dilution end point of 1:10,000. The virus remained active *in vitro* for four days at 18° C. The southern celery mosaic strain (Wellman, 1935 A) had a thermal inactivation point of 75° C. and a dilution end point of 1:10,000. It was active *in vitro* for 6–8 days at room temperature. The southern cucumber mosaic strain, pepper calico strain and the pepper oakleaf strain (Simons, 1957) had a thermal inactivation point of 65–70° C. and a dilution end point of between 1:10,000 and 1:20,000.

#### *Reaction of pepper varieties and control of the diseases*

Kovachevsky (1940) observed that the typical symptoms of the 'rosette' disease were observed on the pepper varietal group known as "Scipki" (with small, pointed fruits). In other (unspecified) varieties the crowding of branches and leaves and the abnormal development of leaves were not so pronounced. Doolittle and Zaumeyer (1953) used the varieties *California Wonder* and *World Beater* in their studies on the ring spot disease. They observed that both the varieties responded similarly to the virus except that the latter variety showed less fruit-spotting. The southern celery mosaic virus has been observed only on the *California Wonder* variety of pepper (Wellman, 1935 A). In a recent study Cook and Anderson (1959) have reported that a strain of *Capsicum annuum*, p. 11, which showed resistance to tobacco mosaic virus, tobacco etch virus and potato virus Y, was completely susceptible to cucumber mosaic virus.

No variety of pepper has been reported to be resistant to the cucumber mosaic virus.

No experimental evidence regarding the efficacy of insecticidal sprays for the control of diseases caused by cucumber mosaic virus is available; but Beattie *et al.* (1944) suggest that the application of nicotine sulphate as sprays or dusts to the crop would be helpful. They also recommend clean cultivation, eradication of weeds like *Commelina* harbouring the cucumber virus, and growing of peppers away from such crops as celery or cucumber.

## 2. Tobacco mosaic virus (*Marmor tabaci* Holmes)

Pepper has been a favourite plant with virologists for transmission studies with tobacco mosaic virus. As early as 1923 Palm reported the transmission of this virus to *Capsicum annuum* and *C. frutescens* in Indonesia. Palm and Jochems (1924) reported the natural occurrence of this virus on pepper plants in the same country. Johnson (1926) reported the artificial infection of pepper plants with, among others, tobacco mosaic virus and "mild tobacco mosaic virus". Tobacco mosaic virus produced striking lesions on the stems of young plants when applied to them with slight wounding. Numerous other reports on the transmission of this virus to pepper and the resulting symptomatology are available (Purdy, 1929; Ainsworth, 1933; Holmes, 1932, 1934 A, 1937 A; Ryjkoff and Karatschëvsky, 1934).

Natural occurrence of tobacco mosaic virus and its strains on pepper plants and the resulting diseases have been described from many countries (*U.S.A.*: Anderson, 1957; Kendrick *et al.*, 1951; Anderson and Corbett, 1957; *Poland*: Panjam and Prpic, 1955; *South America*: Zabala and Delle Costa, 1947; *New Zealand*: Brien, 1942; Chamberlain, 1947; *Trinidad*: Dale, 1943; *Spain*: Anon, 1942; *Portugal*: D'Oliveira 1940; *Ceylon*: Newton, 1953; Peiris, 1953; *Bulgaria*: Kovachevsky, 1942).

Symptoms caused by tobacco mosaic virus on pepper plants are well described by Kovachevsky (1942) from Bulgaria. The disease causes acute as well as chronic symptoms. In the acute phase a cessation of growth takes place 6-7 days after infection. The leaves turn yellow along the veins, sometimes become necrotic and fall off. Stems may also become necrotic so that young plants may be destroyed. If the plants survive the acute phase they begin to grow, though somewhat slowly. The leaves appear bleached and dull with a faint mosaic pattern. Often the green strain of the virus causes a clearer mosaic pattern. The disease is then easily noticed but its total effect is milder and acute damage is not done. Holmes (1937) observed four kinds of symptoms on various varieties of pepper infected with tobacco mosaic virus. These were (1) systemic chlorosis, (2) local lesions on leaves and their consequent shedding, (3) a delayed necrosis combined with a systemic disease and (4) systemic necrosis with stem streaking which under certain conditions results in the death of the plant.



Woods and Eck (1948) described three types of nuclear inclusions in *California Wonder* pepper plants infected with tobacco mosaic virus. These were (1) crystalline proteinaceous inclusions in the cytoplasm, (2) loosely aggregated amorphous proteinaceous precipitates in the cytoplasm and (3) the X body type of inclusions closely resembling the foregoing. The crystalline inclusions were unstable going into solution on mechanical injury to the cell whereas the amorphous precipitates resisted such treatment.

A 'mottle leaf' disease of peppers in Ceylon is reported to be caused by the tobacco mosaic virus (Newton, 1953).

#### *Strains of tobacco mosaic virus on pepper*

1. "*Ring strain*" of tobacco mosaic virus.—Nakata and Takimoto (1940) reported a "ring" strain of tobacco mosaic virus on peppers in Japan. This virus caused large, bright yellow mottling on the leaves. The strain had a dilution end point of 1:1,000,000 and a thermal inactivation point of 90°C.

2. *Marmor tabaci Holmes var. siccans Doolittle and Beecher*.—This strain of virus which caused a necrosis and shrivelling of tomato leaves was reported by Doolittle and Beecher (1942). It passed on to pepper on which it caused symptoms similar to those caused by tobacco mosaic virus. The virus had a dilution end point exceeding 1:1,000,000 and a thermal inactivation point between 90 and 95°C. On dried leaves the virus remained active for seven years and *in vitro* for three years at 21–27°C.

3. *Tobacco paramosaic virus*.—A disease of tobacco called "paramosaic" was described by Kohler and Panjan (1943). The virus of this disease caused local necrosis in White Burley tobacco and other varieties but did not become systemic in them. It had, however, closely similar physical properties to tobacco mosaic virus. This virus strain was sap-transmissible to pepper.

4. *Tomato atypical mosaic virus*.—In 1958 Miller and Thornberry described a disease of tomato and pepper caused by a virus strain which they called tomato atypical mosaic virus. The virus was serologically related to tobacco mosaic virus, but there was no cross-protection. The virus showed rod-shaped particles under the electron microscope measuring  $300 \times 15 \text{ m}\mu$ . It had a dilution end point of  $10^{-8}$  similar to tobacco mosaic virus but was inactivated by exposure to 72°C., in contrast to TMV which had a thermal inactivation point at 85°C. This virus and TMV were inactivated completely at pH 11, markedly at pH 10.5 and slightly at pH 10. When tissues containing the virus were frozen at  $-20^{\circ}\text{C}$ . the virus survived up to 33%, while in crude juice the survival was only 24%. Tobacco mosaic virus on the other had survived up to 90% in crude juice frozen to  $-20^{\circ}\text{C}$ . The virus was unstable at 4°C. while TMV was relatively stable.

On pepper the atypical mosaic virus was difficult to recognise with assurance. The leaves when infected were pale green with only a slight

interveinal chlorosis and without necrosis. The fruits appeared to be incompletely expanded but had no other noticeable characteristics. The stems, blossoms and roots had no symptoms. The general vigour of the plants were slightly reduced.

5. *Tomato streak virus*.—This strain of TMV infects pepper plants and causes a mottling and slight stunting similar to those produced by TMV (Ainsworth, 1933; Chamberlain, 1947).

6. *Strains of TMV on peppers in S. America*.—Diseases of peppers caused by strains of TMV are widespread in Argentina where six such strains were isolated by Zabala and Delle Costa (1947). These strains were from Ullum, Godoy Cruz, Argerich, Alto de Sierra and Resistencia. The first four strains remained active after exposure to a temperature of 80° C. for 10 minutes while the last two were inactivated by this treatment. The strains differed in symptoms produced on Samsun tobacco and Marglobe variety of tomato. Hot chilli varieties *Ruby King* and *Large Bell* developed mosaic patterns when inoculated with all the strains except Argerich. The strain Resistencia caused some defoliation.

7. *Seed-borne strain of TMV*.—McKinney (1952) isolated two strains of TMV from peppers in Beltsville, Maryland, U.S.A. One of these resembled the tobacco mild mosaic 2 of Johnson but did not cause systemic symptoms on tomato. It caused mild symptoms on Samsun tobacco. When this mild strain was inoculated on pepper variety 'South Carolina 46252' only local necrotic lesions developed over a range of temperatures of 68–92° F. This strain had a dilution end point of  $10^{-8}$  and a thermal inactivation point of 88–89° C., for 10 minutes. The virus was highly active for 27 months in dried Samsun tobacco leaves. Another strain of TMV was isolated by the same author from a pungent pepper plant from South Carolina. This strain was latent in Samsun tobacco but induced strong, light green mosaic mottling on the tobacco etch-immune pepper variety SC. 46252. Tests revealed that this latent strain was carried through seed in the etch-immune pepper variety; 21.6% of the seeds gave diseased plants. This seed-borne virus strain had a dilution end point of  $10^{-8}$  and a thermal inactivation point between 85 and 89° C. for 10 minutes. The virus was highly active in dried Samsun tobacco leaves for 18 months.

Anderson and Corbett (1957) conducted a survey of virus diseases of peppers in Central Florida. They found that in this area TMV caused such diseases as 'yellow pod' and 'Ring mottle'.

Newton (1953) and Peiris (1903) reported that a virus disease of pepper called 'mottle leaf' in Ceylon is caused by tobacco mosaic virus. This disease caused a diffuse, irregularly scattered mottle of leaves and slight stunting of plants.

A disease of peppers in Spain called 'Blanqueta' (blanching) was found to be caused by a combined infection by tobacco mosaic virus and tobacco leaf-curl virus (Anon, 1942).



*Reaction of pepper varieties to tobacco mosaic virus and control of the diseases caused*

Reaction of several varieties of pepper to TMV and the pattern of inheritance has been studied by Holmes (1934, 1937). Majority of garden pepper varieties (*Capsicum frutescens*) tested responded to the typical TMV strain by mottling. Yellowish primary lesions developed three days after inoculation followed by chlorosis of young leaves and a prolonged period of reduced growth. Sometimes partial defoliation occurred and yield was reduced. A few varieties—*C. frutescens* var. *Tabasco* and var. *minimum* (*C. minimum* Blanco)—responded with localised necrosis without systemic mottling. These varieties were immune from the serious systemic effects of TMV infection. Many small necrotic lesions developed on the second or third day after inoculation. Affected leaves dropped off between second and fifth day after inoculation. Leaves with many lesions abscised earlier than those with fewer lesions. The plants became free of virus as soon as the inoculated leaves dropped off.

When necrotic type and mottling type plants were crossed it was observed that the ability to localise virus (necrotic response) was inherited as a simple Mendelian dominant character.

In further experiments Holmes (1937) found that the varieties *Long Red Cayenne* and *Sunnybrook Cheese* when inoculated with TMV responded with a few relatively inconspicuous isolated yellowish lesions, which generally became wholly or partly necrotic. These lesions occurred on young leaves at the top of the plant where the virus had established itself in measureable concentration. These semi-necrotic local lesions were called delayed necrosis or imperfectly localised response. When a *Long Red Cayenne* plant was crossed with a plant of mottling type stock the  $F_1$  hybrids showed large primary local lesions which were followed in most plants by severe systemic necrosis. Most of the  $F_1$  plants died within a few days. This fatal systemic necrosis differed from both parental responses. Backcrossing experiments showed that a single partially dominant gene derived from the *Long Red Cayenne* pepper and not present in the mottling type parent determined the systemic necrosis in the  $F_1$  plants. Further experiments showed that the factor for this incomplete localisation was recessive to the factor for complete localisation (L) found in the mosaic resistant varieties referred to earlier. The gene for incomplete type localisation of virus was designated  $l'$  and for mottling type response  $l$ . The gene  $l'$  was found in pepper varieties *Sunnybrook*, *Anaheim chilli*, *Magnum dulce*, *Red cluster*, *Ruby King*, *Sweet Meat Glory*, and *Sweet Mountain*.

In his studies at the University of Missouri Lutes (1954) observed four types of reaction in a series of pepper varieties to TMV. These were (1) Local infection resulting in small chlorotic lesions near infection site followed by necrosis and falling off of infected leaves without systemic spread. (2) Systemic infection of leaves and fruit with chlorotic lesions followed by mottling. (3) Systemic infection

of chlorotic type accompanied by small necrotic lesions on the main stem and (4) systemic infection with dark, necrotic lesions on the main stem. Normal growth and fruit yield were reduced in the case of systemic infection. Cook and Anderson (1959) reported a strain of *Capsicum annuum* P. 11 resistant to TMV.

A single *California Wonder* pepper plant was found uninfected in a heavily infected field in S.W. Missouri. The  $F_1$  progeny from crosses with this plant as one of the parents gave a phenotypic infection ratio of three plants with local necrosis to one with systemic necrosis. Of 100 hybrids and backcrosses carried through the  $F_6$  generation two selections were found promising, their progeny being completely resistant to systemic infection and superior to *California Wonder* variety.

The reaction of several pepper varieties to the tomato atypical mosaic virus was studied by Miller and Thornberry (1958). These are tabulated below. *Anaheim chilli*: necrotic local lesions; *Banana*: mottling and stem necrotic lesions; *Cayenne Long Pod*: necrotic local lesions; *California Wonder*: mottling and stem necrotic lesions; *Golden California Wonder*: mottling and stem necrotic lesions; *Harris Early Giant*: mottling; *Illinois F<sub>51-1</sub>*: necrotic local lesions, mottling; *Large Bell*: necrotic local lesions, mottling; *Mango*: necrotic local lesions, stem necrotic lesions; *Patrick Henry*: necrotic local lesions, mottling; *Pimiento-perfection*: necrotic local lesions, mottling, stem necrotic lesions; *Red Chilli*: mottling; *Ruby Giant*: necrotic local lesions, mottling, stem necrotic lesions; *Ruby King*: necrotic local lesions, stem necrotic lesions; *World Beater*: no symptoms.

*Control*.—Growing of resistant varieties is the only control measure recommended for the diseases caused by tobacco mosaic virus and its strains.

### 3. Tobacco etch virus (Marmor etodens Holmes)

Tobacco etch virus has in recent years been reported to cause a serious disease of pepper in Georgia and Alabama (Greenleaf, 1953, 1956) and in Central Florida (Anderson and Corbett, 1957) of the U.S.A. The disease is called 'vein-banding crinkle' in Central Florida and is said to be the most widespread disease of pepper in that state (Anderson and Corbett, 1957). The disease has also been reported from Ontario, Canada (McKeen, 1953, 1954).

In Alabama several *Tabasco* variety pepper plants wilted in the field because of the disease (Greenleaf, 1953). The first visible symptom following infection of *Tabasco* pepper plants was a faint yellow flecking on the young shoot leaves and vein clearing. These symptoms appeared in 4-21 days after inoculation and were followed or accompanied by wilting of the plants within a few days. The time of onset of symptoms varied greatly depending on the concentration of TEV in the inoculum. With a concentrated inoculum 100% of the plants wilted within 6-10 days. Wilting was usually followed by death but occasionally a few of the young plants about eight weeks from seed showed partial recovery. Such seedlings became severely defoliated but maintained an



apical tuft of leaves, eventually producing some new shoot growth and a few fruits on some of the plants. But these plants remained severely stunted. Larger, older plants always died from the disease. Wilted *Tabasco* pepper plants showed rapid recovery when their stems were severed and placed in water. When the roots of wilted seedlings were severed at soil level, the cut end treated with "rootone" and placed in a coarse sand-rooting medium they produced only a few roots in a four-month period.

Many additional symptoms on pepper produced by TEV have been described by McKen (1954). Three or four days after inoculation chlorotic spots appeared on the inoculated leaves. These leaves later became rugose. The first evidence of a systemic invasion by the virus was a prominent vein clearing of the youngest leaves six to eight days after inoculation. The leaves became mildly chlorotic and showed prominent to moderate cupping. Two or three weeks after inoculation the young leaves showed prominent broad, dark green bands along the veins. These bands were more conspicuous at the base of the lamina than near the tip. Sometimes there was a laminal narrowing and marginal waviness. Much flagging of older leaves on infected plants was noticed. There was severe root necrosis in younger plants and consequently excessive wilting of the plants on hot sunny days. Infected plants were sometimes markedly stunted and bushy in growth. Sometimes main branches had elongated, reddish-brown lesions about 2 mm. wide. On plants that were bearing fruit at the time of inoculation characteristic fruit symptoms consisting of ring and line patterns developed. On green fruits chlorotic shrivelled areas were found more on the side exposed to bright sun. Concentric ringspots in the affected areas were usually slightly elevated. On ripe or ripening fruits various green, orange or brownish colours were found. On some plants with longstanding infection dwarfed or misshapen fruits developed.

Several strains of TEV were present in Ontario. All strains produced crystalline intranuclear inclusions, 1-15  $\mu$  to a cell. In addition, granular amorphous crystals lying close to the nucleus were also found.

*Transmission.*—The virus was easily sap-transmissible. In Ontario *Myzus persicae* is believed to be the principal field vector (McKen, 1954).

*Reaction of pepper varieties to tobacco etch virus.*

In Alabama Greenleaf (1953) found that two varieties of *Capsicum pendulum* Willd., P.I. 152234 (orange coloured fruits) and P.I. 152235 (red-coloured fruits), pepper varieties P.I. 152217 and P.I. 152221 from Peru and the commercial variety Serrano were tolerant to the virus. The pepper varieties P.I. 152222 from Peru and P.I. 152453 from Brazil, *Santanaka*, *Red Chilli*, *Mexican Chilli* and *Burlington* were more severely affected. *Capsicum microcarpon* Cav. from Argentina was also severely affected.

McKen (1954) in Ontario classified the pepper varieties he studied as mild symptom varieties and severe symptom varieties. The former

were *Peru Wonder*, *Vinedale*, and *Hungarian Wax* and the latter *California Wonder*, *Oakview Wonder*, *Golden California Wonder*, *Burpee's Sunnybrook* (pimiento) and *Sweet Hungarian* (*Yellow Banana*). He also found that the late maturing varieties showed pronounced wilting and stunting. Green fruits on the early sweet varieties showed prominent ring patterns on one side of the fruit.

Greenleaf (1956) has studied the inheritance of reaction to TEV in *Capsicum annuum* and *C. frutescens*. Resistance in *C. annuum* var. *cayenne* (South Carolina No. 46252) and *C. frutescens*, P.I. 152225 from Peru was inherited non-factorially and was determined by recessive genes. The genes for resistance in the two species of *Capsicum* were assigned the symbols  $et'$  and  $et''$ , the superscripts denoting their respective species origin. It is not known whether these genes were alleles. In *C. annuum* (S.C. 46252) some apparently immune plants were found and it is probable that these plants contain one or more modifying genes which raise the resistance to this level.

Cook and Anderson (1959) found that a variety of *C. annuum* designated P. 11 was tolerant to five strains of TEV but resistance to two others was less evident.

#### 4. *Alfalfa mosaic virus* (*Marmor medicaginis* Holmes)

Alfalfa mosaic virus affects peppers in Germany and Italy (Quantz, 1956). Young infected pepper plants (*C. annuum* var. *Hoffman's Aurora* and *Long Red Cayenne*) developed curled leaves with a mosaic of bright yellow green streaks and flecks. Plants infected when young remained stunted and leaf deformation was considerable.

The 'variegation' disease (*Buntblattigkeit*) of peppers in Bulgaria is caused by the alfalfa mosaic virus. The disease is characterised by large conspicuous white or yellow flecks on the leaves (Kovachevsky, 1942). In many cases, especially in artificial infections, the entire leaf blade or part of it is coloured pale or bright yellow. Leaves are sometimes malformed and fruits may be distorted. Mechanical transmission as well as transmission by the vector *Myzus persicae* were successfully carried out by Kovachevsky (1942). The loss in yield by this disease is reported to be less than that caused by cucumber mosaic virus and tobacco mosaic virus.

#### *Strains of alfalfa mosaic virus*

1. *Potato calico virus* (*Marmor medicaginis* Holmes var. *solani* Holmes).—Artificial transfer of potato calico virus to pepper was reported from California (Anon, 1933; Porter, 1935). The latter infected the pepper variety *Ruby King*. Death of the entire plant resulted from the infection. Oswald (1950) also reported successful infection of *California Wonder* peppers by this virus and by another strain of alfalfa mosaic virus causing tuber necrosis in potato. Both viruses infected pepper systemically, the symptoms being indistinguishable. Both caused local reddish necrotic lesions on the rubbed leaves in 7–10 days after inoculation. Secondary symptoms were chlorosis of the



upper halves of the leaves and dark green vein-banding. The veins were rough and warty. The tuber necrosis strain had a thermal inactivation point of 53–55° C. and was active *in vitro* for 72–96 hours at 16° C.

2. *Marmor medicaginis* Holmes var. *Capsici* Berkeley.—In Brant and Lincoln counties of Ontario, Canada, Berkeley (1947, 1947 A) observed an unusual mosaic of pepper (*California Wonder* variety). The disease was characterised by mottling, chlorotic ringspots and line patterns on both leaves and fruits. Extensive host-range studies revealed that the virus involved was a strain of alfalfa mosaic virus. The typical strain of alfalfa mosaic virus and the potato calico strain also gave symptoms of the same general pattern on pepper. The pepper strain had a thermal inactivation point of 63–64° C. Certain differences in host reaction, however, indicated that the pepper strain was different and was therefore considered new and designated *M. medicaginis* var. *capsici*.

The 'Buntblattigkeit' or variegation disease of pepper in Yugoslavia is reported by Sutic (1959) to be caused by the above strain of alfalfa mosaic virus. The disease was found to be seed-borne in Yugoslavia to a small extent (1–5%, average 2%).

3. *Marmor medicaginis* Holmes var. *Ladino* Kreitlow and Price.—Kreitlow and Price (1949) described a disease of ladino clover caused by a strain of alfalfa mosaic virus. They considered this strain to be new. The virus passed on to pepper causing systemic mottling, distortion and chlorosis in the tissues affected. The virus strain had a thermal inactivation point of 62–63° C. and a dilution end point of 1:100. The virus was active *in vitro* for 48 hours at 18–20° C. and for 60 minutes at 28° C.

#### 5. *Pepper vein-banding mosaic virus*, Simons

A disease of *California Wonder* peppers caused by this virus has been described by Simons (1956) from the Everglades area of Florida. The disease caused an yield loss of up to 50%. Leaves of diseased plants were somewhat chlorotic and showed a marked vein-banding. Infected fruits were roughened and displayed chlorotic spots and/or stripes. Initial symptoms appeared 7–10 days after inoculation and the vein-banding was visible in three weeks. Shaded pepper plants developed more severe symptoms than those in bright sunlight. While pepper varieties *California Wonder* and *Yolo Wonder* developed vein-clearing, severe mottle, vein-banding and leaf distortion, the varieties *Tabasco* and *Longum* did not show vein-banding but had vein-clearing, severe mottle or mild mottle.

The virus had a thermal inactivation point of 60–65° C. and a dilution end point of 1:20,000. It was active *in vitro* for 10–15 days at 25° C.

The virus was sap-transmissible and also by the vectors *Myzus persicae* and *Aphis gossypii*. It was non-persistent in both these vectors. *Aphis rumicis* did not transmit the virus. *Myzus persicae* was able to acquire the virus in a feeding time of 5 seconds or less. Percentage

transmission increased with increase of feeding time up to 5 minutes. Longer periods of feeding increased transmission only slightly. While a two minutes starvation period following acquisition feeding caused a noticeable drop in infectivity, one-hour periods caused almost complete loss of infectivity.

Simons (1957) tested the effect of insecticides and physical barriers on field spread of vein-banding virus on pepper. Nightshade (*Solanum gracile*) was the primary source of the virus in the field. It was observed that a distance of 150 feet between plants could effectively limit the spread of the virus. The use of parathion and demeton as aphicides on pepper had no effect in limiting the spread of the disease. Parathion used on the host, however, significantly reduced virus spread.

The effect of placing a vertical physical barrier between the source of inoculum and the crop was investigated to a limited extent. Use of sunflower as a barrier plant resulted in a significant decrease in virus spread. Demeton sprays on the sunflower barrier at three-week intervals did not significantly increase the efficiency of the barrier.

#### 6. *Potato virus Y* [Marmor upsilon (*Holmes*) *Holmes*]

Potato virus Y has been reported to occur naturally on peppers in Florida (Anderson, 1956; Anderson and Corbett, 1957; Simons, 1959), Hawaii (Sakimura, 1953) and in Bulgaria (Kovachevsky, 1942). In Florida it causes a vein-banding disease of pepper resulting in considerable loss. The widespread occurrence of this disease in Florida has been traced to the recent introduction of potato cultivation (Simons, 1959). The virus overwinters on weed hosts like *Solanum gracile* and is spread by the aphid *Myzus persicae*. In Bulgaria the disease caused by this virus is characterised by vein clearing and mosaic flecking of leaves. In spite of the widespread occurrence of this virus on potatoes in Bulgaria it is said to be rare on pepper (Kovachevsky, 1942).

David and Stormer (1941) showed that *Capsicum annuum* plants were good test plants for potato virus Y. On inoculated plants the symptoms started as indefinite flecks on the leaves and a slight swelling of the nerves on the larger young leaves. Soon a finely divided intercostal flecking developed till the entire leaf had a dark green mottle. Somewhat older leaves had a waviness of their margins. Curling and deformation of leaves were not observed. In older plants the chlorophyll of the leaves between the veins was completely destroyed. There were completely white zones and small green areas near the veins.

Bohme (1933) reported transmitting a strain of potato virus Y to three strains of pepper.

Cook and Anderson (1959) reported a strain of *Capsicum annuum* designated P. 11 as showing multiple virus resistance to tobacco mosaic virus, tobacco etch virus and potato virus Y. Plants inoculated with five strains of potato virus Y failed to show any symptoms even after five months. They found that the virus could move through the stems



of P. 11 plants but could not multiply within them. In a later communication Cook and Anderson (1960) reported that the variety S.C. 46252 was also resistant to this virus while the varieties *California Wonder*, *Florida Giant*, *Improved World Beater* and *Yolo Wonder* were susceptible. Resistance to potato virus Y in both resistant varieties was found to be inherited as a single recessive factor denoted by the symbol  $y^a$ . Both the varieties were homozygous for the recessive allele while the susceptible varieties listed above were homozygous for the dominant allele  $Y^a$ .

7. *Cranberry false-blossom virus* (*Chlorogenus vaccinii* Holmes)

*Syn. Chlorogenus australiensis* (Holmes) Holmes, *Stolbur virus*, *tomato big bud virus*

This virus is reported to occur naturally on pepper in Austria (Wenzel, 1956) and Russia (Sukhov and Voik, 1946, 1947; Feiginsan, 1936). In Russia it is reported to cause mass wilting of pepper plants (Sukhov and Voik, 1957) and to cause considerable loss in the Crimea, Moldavian S.S.R., Azoff-Blacksea littoral, Armenia, Stalingrad and the Saratoff Volga basin (Feiginsan, 1936). The virus is also reported to infect pepper in Czechoslovakia (Blattny *et al.*, 1954).

NOTE:—Smith (1957) considers the *stolbur virus* and the *tomato big bud virus* as synonyms of the *cranberry false-blossom virus*.

8. *Tomato spotted wilt virus* (*Lethum australiense* Holmes)

Artificial transmission of this virus to pepper has been reported by Smith (1932, 1936) and Van Schreven (1935). The latter observed that pepper plants stopped growth three weeks after inoculation with this virus.

The virus has been reported to occur naturally on peppers in Mexico (Ploper, 1948), U.S.A. (Chupp, 1937; Gardner and Whipple, 1934; Gardner, Tompkins and Thomas, 1937; Pirone, 1935; Kendrick *et al.*, 1951). The disease caused by this virus was considered serious by Gardner and Whipple (1934) and to cause moderate to heavy losses (Kendrick *et al.*, 1951). Pirone (1935) reported that pepper plants affected by this virus developed large ringspots on fruits and leaves especially on the *California Wonder* variety. The ringspots on pepper strongly resembled those produced on tomato by the same virus. Needle prick inoculations on pepper plants produced marked dwarfing together with considerable mottling and slight deformation of the leaves. Chupp (1936) reported that in California there was a 100% infection by this virus in 1936. However, in 1937 when the weather was unusually wet and warm in August there was no incidence of the disease.

A disease of peppers caused by this virus is called 'peste blanca' (White pest) in Mexico (Ploper, 1948). It is spread by the thrips *Frankliniella paucispinosa*.

9. *Beet curly-top virus* (*Ruga verrucosans* Carsner and Bennett)

Severin (1929) observed natural infection of peppers by this virus in various localities in California. Four varieties, *Anaheim Chilli*, *Paprika*, *Pimiento* and *Mexican Chilli* were found naturally infected. In the Sacramento valley up to 79% infection was noticed in a *Pimiento* pepper field. The plants were stunted with thick leathery leaves. Severin (1929) infected the following varieties of pepper artificially: *Anaheim Chilli*, *California Wonder*, *Chinese Giant*, *Large Bell* or *Bull Nose*, *Long Red Cayenne*, *Mexican Chilli*, *Pimiento*, *Red Chilli*, *Royal King*, *Ruby King*, *Sweet Mountain*, *Sweet Upright*, and *Tabasco*. The symptoms of infection were an inward curling of young leaves and a outward cupping of the somewhat older leaves. The veinlets became transparent in the youngest leaves. Minute swellings developed on the network of cleared veins. Transparent veins were not observed in naturally infected plants.

Dana (1934) has reported an yield loss of 10–25% in peppers due to this virus in the Pacific Northwest of the U.S.A. A loss of 50–60% has been reported from New Mexico (Leyendecker, 1950) and 5–40% in Arizona (Anon, 1951).

The potato curly top virus (a strain of beet curly top virus) has been transmitted to peppers by grafting (Menzies and Giddings, 1953).

10. *Tobacco leaf-curl virus* (*Ruga tabaci* Holmes)

A disease of peppers in Spain called 'Blanqueta' (blanching) is reported to be caused, probably, by a combined infection of tobacco leaf-curl virus and tobacco mosaic virus (Sardina, 1940). The symptoms of the disease are mottling and crinkling of the small and medium-sized leaves and a chlorotic leaf mottle. On larger leaves crinkling was less noticeable. The skin of the affected fruits had a granular texture with striations and slight creasing. The disease was transmitted by *Myzus persicae* and also by mechanical means. This makes it doubtful whether the viruses involved have been correctly identified as tobacco leaf-curl is generally transmitted by whiteflies and tobacco mosaic virus has no insect vectors at all.

A disease of peppers called 'vein-clearing' in Ceylon is reported by Peiris (1957) to be caused by the 'Transparent Kroepoek' strain of tobacco leaf-curl virus. This disease was transmitted by the whitefly *Bemesia inconspicua*, the incubation period inside the vector being 8 days. The tender leaves near the growing point showed the first symptoms of infection. The areas immediately bordering the veins showed yellowish tinges against the light green of the interveinal regions. As the leaf hardened it became boat-shaped, the leaf margins curling upwards and the yellowing along the veins becoming more distinct. The later formed internodes were shortened. By the 18th day the leaf symptoms of vein-clearing became clearly marked.

Peiris (1953) tested the reaction of five varieties of pepper against this disease. The varieties *Tokiyam Pololy*, *Neelam Suthumalay*,



*Local Myliddy*, *Black Mathakal* and *Local Tinnevelly* were found to be susceptible.

Insecticidal sprayings against the vector did not control the spread of the disease.

A leaf-curl of pepper in India is mentioned by Husain (1932) and Vasudeva (1954). It is not clear, however, whether this disease is the same as that occurring in Ceylon.

11. *Aster ringspot virus* (*Annulus wellmanii* Anderson)

This virus was described by Anderson (1945) from Florida, U.S.A. The virus was naturally present in peppers and in China Aster (*Callistephus chinensis*). The disease on peppers (*C. frutescens*) was observed in the Sanford-Samsula and Tampa areas of Central Florida. The disease was characterised by chlorotic ring, line and oakleaf patterns on the leaves. Affected plants were not noticeably stunted and bore normal fruit. Chlorotic patterns were brilliant often consisting of chlorotic rings. Systemic necrotic patterns also sometimes developed. Pepper leaves did not outgrow the symptoms. *Aphis gossypii* and *Myzus persicae* did not transmit the virus but sap inoculations were successful. The virus was inactivated at 75–80°C.

A disease of peppers described by Swank (1952) from the same area in Florida is apparently caused by the Aster ringspot virus. The symptomatology is the same; however, Swank observed that in some affected fields plants were stunted and did not set fruit.

12. *Trinidad Chilli (pepper) mosaic virus*, Ferguson

Ferguson (1951) has described a mosaic disease of peppers from Trinidad which has symptoms quite distinct from those caused by tobacco mosaic virus on peppers in that country. Symptoms of this disease appear 8–12 days after inoculation and consist of vein-clearing of the expanded foliage followed by mottling. On later-formed leaves irregular and discontinuous vein bandings appear with dark and light green mottling of the interveinal regions. Laminæ were reduced in size and had a crinkled appearance. Fruits were smaller, abnormally twisted and blistered. Fruit deformities were seen more in the large fruited sweet peppers (*C. annuum* var. *grossum*) than in the hot peppers (var. *minimum*). Bird and cherry peppers (*C. frutescens*) also showed leaf symptoms. *Large Bell Hot* variety of hot peppers ceased growth early with rapid necrosis, defoliation and death.

The virus was inactivated at a temperature of 63°C. and had a dilution end point of 1 : 5000. It was active *in vitro* for 16 days at 15°C.

13. *Indian Chilli mosaic virus*, Jha and Raychaudhuri

A mosaic disease of peppers is widespread in India (McRae, 1924, Kulkarni, 1924; Uppal, 1929; Vasudeva, 1954; Jha and Raychaudhuri, 1956). Kulkarni (1924) reported that in the Bombay presidency the disease caused considerable reduction in yield. Diseased plants had

distortion of leaves with blistering and pronounced mottling. The leaves were reduced in size, sometimes becoming tendril-like. Flowers and fruits were absent when the disease set in early. In case of late infection fruits were small and distorted.

Jha and Raychaudhuri (1956) made a detailed study of the disease including the properties of the virus. The virus was transmitted by *Aphis gossypii* (Vasudeva, 1954; Jha and Raychaudhuri, 1955). It had a thermal inactivation point between 55 and 60° C. and a dilution end point between 1:25,000 and 1:30,000. The virus was active for 15–22 days at room temperature. It was inactivated immediately by 50% nicotine sulphate and 1% silver nitrate; in four hours by 50% ethyl alcohol and in 24 hours by 0.5% silver nitrate and 0.25% phenol. Exposure to ultra-violet light (342–72 m.u.d) for 4 hours did not inactivate the virus while exposure for six hours did. The virus was not seed-transmitted.

Nariani and Sastry (1958) found that the virus could be transmitted by *Myzus persicae*, and *Aphis evonymi* in addition to *Aphis gossypii*. While *M. persicae* and *A. gossypii* were equally efficient *A. evonymi* was much less so. *Lipaphis erysimi* did not transmit the virus.

Uppal (1930) reported a mosaic disease of chilli in the Bombay State which was transmitted by a species of thrips. This is apparently a different disease from the one described above.

#### 14. Puerto Rican pepper mosaic virus, Roque and Adsuar

A mosaic disease of peppers in Puerto Rico was recorded by Cook (1929, 1930). This disease has been studied in detail by Roque and Adsuar (1939, 1941). The disease was reported to cause a loss of 50–60% in yield in certain areas of Puerto Rico. All susceptible varieties of pepper except the *Large Bell Hot* variety develop the following symptoms 10–12 days after inoculation. A marked clearing of the veins developed in the upper younger leaves followed later by a systemic mottling with ultimate vein-banding. Vein-banding was the most characteristic symptom in the field. The leaves became wrinkled and the whole plant was stunted if infection had taken place early. Fruit production was curtailed and fruits produced after infection were undersized, mottled and badly distorted. Younger plants were more seriously and rapidly affected than older plants. In young, actively growing plants of the variety *Large Bell Hot* the virus produced a systemic vein necrosis in 5–6 days followed by defoliation, stem streaking and death of the entire plant. A survey of the island showed that the disease was prevalent in 60–95% of the plants in the field.

The virus was easily sap-transmissible and also by the vector *Myzus persicae*. The thermal inactivation point lay between 55 and 58° C. and the dilution end point a little above 1:100. The virus was completely inactivated after an *in vitro* storage of 48 hours at 22° C. Immunological studies showed that the virus was not related to tobacco mosaic virus, potato mottle virus (ringspot strain) and the potato vein-



banding virus. The properties of the virus were similar to those of potato virus Y, but there were wide differences in symptomatology. Serological studies by Perez and Adsuar (1955) also showed that the potato virus Y and the Puerto Rican pepper mosaic virus were closely related, but the latter had an antigenic component not found in potato virus Y. The virus had also close resemblance to potato virus A in its physical properties and in symptomatology on *Nicotiana tabacum*. The properties of this virus are very different from those of pepper vein-banding virus reported by Simons (1956) from Florida.

Roque and Adsuar (1941) tested 81 varieties of peppers for resistance to the virus and found that two, a Mexican hot pepper called *Cuaresmeno* and a native hot pepper were resistant. A strain of pepper developed by F. O. Holmes in the U.S.A., which reacted with localised necrotic lesions against tobacco mosaic virus, reacted with systemic mottling against the Puerto Rican virus. The variety *California Wonder* developed vein-clearing, mottling, vein-banding and stunting when inoculated with the virus. By crossing the *California Wonder* variety (susceptible) with the resistant variety *Cuaresmeno*, a strain of pepper resistant to the disease has been bred by Riollano, Adsuar and Rodriguez (1948).

#### 15. *Trinidad pepper vein-banding virus*, Dale

A vein-banding disease of pepper was reported by Dale (1954, 1956) to occur naturally and reduce the yield of sweet peppers in Trinidad. The disease was readily sap-transmissible and by the vector *Aphis gossypii*. On most varieties of pepper the virus caused slight vein-clearing of expanding leaves in 7–10 days followed by mottling. Ultimately an irregular and discontinuous dark green vein-banding often bordered by chlorotic areas merging in darker interveinal tissue developed on the leaves. The leaves were crinkled and reduced in size. Infected plants of *California Wonder* and *Fordhook* varieties were stunted and gave reduced yields of smaller misshapen fruits.

The virus had a thermal inactivation point of 62°C. and a dilution end point of  $2 \times 10^{-5}$ . It was active *in vitro* for 6 days at a temperature of 25–30°C.

There was considerable variation in the reaction of various varieties of peppers to the virus. Certain local red and yellow fruited hot peppers (*C. annuum* var. *minimum*) showed resistance to the disease. Perennial small fruited bird peppers and cherry peppers (*C. frutescens*) often showed clear leaf damage but no other symptoms. Young plants of *Large Bell Hot* variety of *C. annuum* showed dark brown vein necrosis of the developing leaves 4–8 days after infection, followed by necrotic stem streaking, abscission of all but oldest leaves and death of plants. Dark brown local lesions occasionally appeared a day or two before systemic necrosis. Older plants turned chlorotic, developed necrosis of the active shoots and shed their fruits, but often survived in a moribund condition. Hybrids of *Large Bell Hot* and other varieties were stunted, produced little or no fruit and had small and curled leaves with varying degrees of vein-clearing.

Dale (1954) thought that the Trinidad pepper vein-banding virus was probably related to the pepper mosaic virus of Puerto Rico described by Roque and Adsuar (1941). However, an examination of the physical properties of these viruses shows considerable differences. The Trinidad virus is probably related to or is the same as the pepper vein-banding virus described by Simons (1956) from the U.S.A. They have closely similar physical properties and produce comparable symptoms on pepper.

#### 16. *Italian pepper mosaic virus*, Ajroldi

Ajroldi (1939) described a mosaic disease of peppers in Italy which caused a loss in yield of 50–70% in the vicinity of Milan. First symptoms of the disease appeared 30–60 (sometimes 100) days after transplanting. Large fruited varieties showed two types of symptoms: (1) typical 'aucuba' mottling, chlorotic spots often merging into irregular white to yellowish spots with darker edge generally confined to leaf apices and margins. Sometimes the discoloured parts appeared as alternate light and dark concentric rings. (2) The marbling type spots in serpentine lines frequently starting near the leafstalks, with uniform discolouration near the veins. Both types were accompanied by fleshy or leathery leaf swellings and malformations. Spots were sometimes found on petioles and stems also. Symptoms first developed on young leaves and in a fortnight the entire plant looked abnormal. Growth was arrested and the plants looked rachitic, pinched and sickly. Fruit-set was reduced, the few fruits set after infection being dwarfed and misshapen. Medium and small fruited varieties escaped much damage.

In diseased leaves palisade cells were isodiametrical, irregular and often arranged in two or more superimposed layers. The spongy tissue was parenchymatous. Chloroplasts were less numerous, arranged in irregular masses and poor in chlorophyll. X bodies were present.

The virus was mechanically transmitted. Gualaccini (1956) also succeeded in transmitting the disease by means of *Cuscuta pentagona*, to peppers and Perustitza tobacco. On this basis Gualaccini thinks that the disease was caused by a strain of tobacco mosaic virus.

The disease appeared to be favoured by sudden changes in atmospheric temperature, heavy applications of nitrogenous fertilizers and frequent irrigation with cold water.

Ajroldi (1939) suggests that the disease is probably the same as the 'niebla nueva' of Spain reported by Bennloch and Dominguez (1934) (see also under 'cucumber mosaic virus').

#### 17. *Pepper yellow leaf virus*, Heuberger

An apparently new virus (?) disease of peppers was noticed by Heuberger (1944) in Delaware, U.S.A. The disease was characterised by a continuous yellow discolouration of the leaf beginning at the petiole and extending towards the leaf apex. These leaves were easily shed.



Fruits present at the time of infection developed yellow discolouration often accompanied by pitting. Fruits set after infection did not develop.

#### VIRUSES ARTIFICIALLY TRANSMITTED TO PEPPER

##### 1. *Potato virus X* [Annulus dubius (Holmes) Holmes]

Blodgett (1927) demonstrated that symptoms of a disease appeared when peppers were inoculated with juice from apparently healthy potatoes. The virus concerned was probably potato virus X. Symptoms appeared in 10 days under favourable conditions. First symptoms were rather indefinite light spots in the young leaves developed after inoculation. The spots, about 0.5 cm. in diameter, quickly died and turned brown in colour. As spots developed on rapidly expanding young leaves these leaves became wrinkled and distorted and were shed, the plants retaining the leaves produced prior to inoculation. Necrotic streaks spreading from point of inoculation were produced on the stems also. All young leaves, subsequently produced, also became necrotic and were shed. Plants remained dwarfed. The varieties of potatoes from which the virus was obtained were *Green Mountain*, No. 9, *Cobbles*, *Rural Russets*, *Heavy Weights* and *Bliss Triumph*.

Vand der Meer (1932) studied a virus obtained from apparently healthy potatoes of the variety *Green Mountain*. Two varieties of *C. annuum* when inoculated with juice from potatoes developed necrosis. About 2-3 weeks from inoculation the leaves at the top became wrinkled and somewhat mosaic mottled. Necrotic spots appeared on the laminae, petioles and stems. In one of the varieties the leaf spots were much more developed than in the other. Very often the petiole bent at the necrotic spot and in such cases the laminae wilted and died. The plants were stunted but not killed by the virus. New leaves were small, distorted, had light green and necrotic areas and mostly fell off soon.

The virus had a longevity *in vitro* of 18 days, a thermal inactivation point of 75° C. and a dilution end point of 1:100,000 to 1:1,000,000. Sixty-four per cent alcohol inactivated the virus.

Bohme (1933) transmitted potato virus X to three varieties of pepper but did not describe the resulting symptomatology.

Chester (1936) observed that a latent potato strain of the virus caused a severe systemic necrosis on pepper. Similar observations were made by Schultz *et al.* (1937) and Roland (1950).

Salaman (1938) studied six strains of the virus obtained from potato. The strain X<sup>h</sup> produced distinct reaction on pepper plants while the other five were masked. This strain remained active in raw unclarified juice for four months at room temperature, had a particle size of 133 mμ, a dilution end point of 1:3000, and a thermal inactivation point of 58° C.

David and Stormer (1941) demonstrated that *C. annuum* was a good test plant for potato virus X and developed characteristic primary

and secondary symptoms on inoculation. As primary symptoms, necrotic dark rings were produced on inoculated leaves. These rings became lesions when virulent strains of the virus were used. Secondary symptoms were a bleaching and puckering of the younger leaves and sometimes necrosis and death of the entire apex.

Maris and Rozendaal (1956) also observed that pepper plants were useful indicator plants for potato virus X.

2. *Tomato bushy stunt virus* (Marmor dodecahedron, Holmes)

There is a single doubtful report by Gigante (1955) of this virus being transmitted to pepper.

3. *Potato leaf roll virus* (Corium solani Holmes)

There is a single report of this virus being transmitted to pepper by the vector *Myzus persicae*, from Oregon, U.S.A. (Anon, 1930).

4. *Tomato ring-spot virus* (Annulus zonatus Holmes)

Kohler (1940) reported that a strain of this virus (Pomeranian strain) caused a delayed necrosis of pepper involving petioles, leaf blades and veins. Samson and Imle (1942) reported experimental infection of pepper variety *Ruby King* with this virus.

5. *Potato aucuba mosaic virus* (Marmor aucubæ Holmes)

Clinch, Loughnane and Murphy (1936) and Maris and Rozendaal (1956) have reported experimental transmission of this virus to pepper. The former observed brown or purple bordered spots followed by rusty purple discolouration on inoculated pepper plants.

6. *Potato stunt virus*, Cockerham and McGhee

Pepper plants when experimentally infected with this virus became chlorotic, stunted and distorted (Cockerham and McGhee, 1953).

7. *Sweet-potato mosaic virus*, Elmer

Pepper seedlings were killed when sap-inoculated with this virus from sweet-potato (Elmer, 1957). The virus had a dilution end point of  $10^{-6}$  and a thermal inactivation point of  $90^{\circ}\text{C}$ . It was active in tobacco leaf extract for 67 days at room temperature.

8. *Broad bean vascular wilt virus*, Stubbs

Experimental infection of peppers with this virus produced systemic chlorotic rings followed by irregular, dark green mottle (Stubbs, 1947).

9. *Carrot motley dwarf virus*, Stubbs

This virus was reported by Stubbs and Grieve (1944) from Australia. The virus passed on to pepper plants experimentally by the vector *Cavariella aegopodii*. Infected pepper plants developed small feeding

lesions on older leaves in 12–14 days. Systemic symptoms consisting of light and dark green mottle, with slight blistering of young leaves, developed seven days later. Chlorotic rings appeared transiently on the older leaves and complete symptom-masking occurred with rising temperature.

10. *Yam mosaic virus*, Adsuar

This virus was reported by Adsuar (1955) on yam, *Dioscorea rotundata* from Puerto Rico. The virus was mechanically transmissible to pepper plants. The virus had a thermal inactivation point of 60° C. and a dilution end point of 1:10,000. It was active for one month at –5° C. while at room temperature the infectivity of expressed sap was lost in 24 hours. In air-dried material the virus was active for 24 days.

11. *Sunflower mosaic virus*, Traversi

This virus which was reported on sunflower (*Helianthus annuus*) from Argentina by Traversi (1949) was sap-transmissible to peppers. It was also transmitted by the vectors *Thrips tabaci*, *Myzus persicae* and *Trialeurodes vaporariorum*. This if confirmed is quite unusual. The thermal inactivation point of the virus was 96–99° C. and the dilution end point 1:100,000.

12. *Radish stunt virus*, Isiyama and Misawa

A virus causing a stunt disease of radish was reported from Japan by Isiyama and Misawa (1943). The virus was transmitted by the vectors *Myzus persicae* and *Rhopalosiphum pseudobrassicae*. The virus infected pepper.

13. *Trinidad tomato twisted leaf virus*, Ferguson

This virus reported by Ferguson (1951) from Trinidad was artificially transmissible to peppers by grafting. It was not sap transmissible. Six days after sap inoculation pepper leaves developed variegation of ill-defined dark and light patches. In ten days the veins showed some yellowing and the leaves became somewhat blistered.

14. *Trinidad tomato bronze leaf virus*, Ferguson

This virus was sap-transmissible to pepper variety *Fordhook* (Ferguson, 1951). The pepper leaves developed an yellowing along the veins with interveinal chlorotic patches developing later. The virus had a thermal inactivation point of 40° C. and a dilution end point of 1:10,000. It was active *in vitro* for three weeks at 15° C.

15. *Trinidad eggplant mosaic virus*, Ferguson

This virus reported from Trinidad by Ferguson (1951) was sap-transmissible to pepper producing sparse irregular chlorotic lesions on leaves. The virus had a thermal inactivation point of 65° C. and



a dilution end point of 1:10,000. It was active *in vitro* for three weeks at 15° C.

#### 16. *Tomato necrosis virus*, Chamberlain

This virus was reported from New Zealand by Chamberlain (1940). It caused a severe streak disease of tomatoes in combination with tobacco mosaic virus. It could be freed from TMV by passage through tree tomato (*Cyphomandra betacea*). The virus was transmissible to pepper. About seven days after inoculation local lesions appeared on inoculated leaves. The lesions were irregular in shape, about 1/16 to 1/8" in diameter and of light brown colour with dark brown margins. Secondary symptoms consisted of light and dark green mosaic mottling of leaves sometimes associated with dark brown necrotic areas. Occasionally necrotic areas appeared as narrow bands which tended either to follow the veins or form circles or irregularly shaped rings. Infected plants were considerably stunted and failed to set fruit.

The virus had a thermal inactivation point of 64–66° C. and a dilution end point of 1:500,000 to 1:1,000,000. The virus was active for over 17 weeks *in vitro* at 22° C.

#### 17. *Tomato yellow mosaic virus*, Stover and Vermillion

Stover and Vermillion (1933) described a yellow mosaic of tomato in the United States. The virus causing this disease was transmitted to pepper and was much more injurious than ordinary tomato mosaic virus. In inoculated plants the leaves and blossom buds dropped off and many of the plants were killed. The virus had a thermal inactivation point of 83° C. in contrast to 90° C. of ordinary tomato mosaic virus.

### UNIDENTIFIED VIRUSES ON PEPPER

There are many reports in literature about unidentified virus diseases on pepper. Such diseases are designated by common or local names without any information on symptomatology or properties of the viruses concerned. Such reports are summarised below:

*Mosaic*.—Africa and neighbouring islands (McKinney, 1929, Shepard, 1931); U.S.A. (Higgins, 1923; Martin, 1930; Webber, 1932; Erwin, 1932); South America (Abbot, 1931; Palm, 1932; Miller, 1936; Soriano, 1932); Burma (McRae, 1929; Su, 1936); Ceylon (Fernando and Peiris, 1957); China (Ho and Li, 1936); Denmark (Anon, 1934); Indonesia (Van Hall, 1924; Van Schreven, 1948); Italy (Gualaccini, 1956); Malaya (Burnett, 1947); Mexico (Brawer and Richardson, 1957); Rumania (Suvaescu *et al.*, 1934) "*Variegation Disease*"; Japan (Ikano, 1930); "*Pox*", Indonesia (Thung, 1939); "*Psyllid Yellows*"; U.S.A. (Binkley, 1930) artificial infection); "*Leaf Curl*"; China (Tu, 1933); Mexico (Brawer and Richardson, 1957); "*Leaf-Crinkle*"; Africa (Deighton, 1929); "*Little Leaf*"; Ceylon (Park, 1932, 1935; Fernando and Peiris, 1957).

## REFERENCES

- ABBOT, E. V. 1931. Further notes on plant diseases in Peru. *Phytopathology* **21**: 1061-71.
- ADSUAR, J. 1955. A mosaic disease of the yam, *Dioscorea rotundata* in Puerto Rico. *J. Agric. Univ. P.R.* **39**: 111-13.
- AINSWORTH, G. C. 1933. An investigation of tomato virus diseases of the mosaic, 'stripe', streak group. *Ann. appl. Biol.* **20**: 421-28.
- AJROLDI, P. 1939. Il mosaic de peperone, *Riv. pat. veg. Pavia.* **29**: 399-422.
- ANDERSON, C. W. 1954. The Aster Ringspot viruses of Florida. *Phytopathology* **44**: 87-92.
- . 1956. *Ann. Rept. agric. Res. Stn., Fla.*, for year ending June, 30, 1955.
- . 1957. *Ibid.* 1956.
- AND CORBETT, M. K. 1957. Virus diseases of peppers in Central Florida, survey results. *Plant. Dis. Repr.* **41**: 143-47.
- ANON. 1930. Department of Botany and Plant Pathology, *Oregon agric. expt. Stn.*, Director's Bienn. Rept. **1926-28**: 78-82.
- . 1933. Serving California Agriculturae. *Rept. Calif. agric. expt. Stn.* July 1, 1931-June 30, 1932, 1-106.
- . 1934. Plantesygdomme i Denmark 1933, Oversigt, samlet ved Statens Plantepatologiske Forsig, *Tidsskr. Planteavl.* **40**: 258-350.
- . 1941. Memoira los realizados por la Estacion de Fitopatologia agricola la Coruna Anos 1939-40. *Publ. Estac. Fitop. agric. Coruna.* **14**: 1-35.
- . 1942. Laboratorio de Cryptogamia ex Memoria Estacion de Fitopatologia Agricola de la Coruna 1942. *Ibid.*, **23**: 21-57.
- . 1951. Sixty-first annual report for the year ending June 30, 1950. *Tucson Univ. Arizona agrl. expt. Sta.* 88 pp.
- BEATTIE, J. H., DOOLITTLE, S. P., BEATTIE, W. R., MAGRUDER, R. AND WEBSTER, R. E. 1944. Production of peppers, *Leafl. U.S.D.A.* **140**: 7.
- BENNLOCH, M. AND DOMINGUEZ, F. 1934. La enfermedad de los Pimentales en Aldenueva de Camino. *Bol. Pat. veg. Ent. agric. Madr.* **7**: 1-20.
- BERKELEY, G. H. 1947. Alfalfa mosaic on pepper in Ontatio, Abstract. *Phytopathology* **37**: 3.
- . 1947 a. A strain of alfalfa mosaic virus on pepper in Ontario. *Ibid.* **37**: 781-89.
- . 1951. Gladiolus viruses, Abstract. *Ibid.* **41**: 3-4.
- BINKLEY, A. M. 1930. Transmission studies with a new psyllid yellows disease of Solanaceous plants (a preliminary report). *Proc. Amer. Soc. hort. Sci.* **27**: 248-54.
- BLATTNY, C., BREAK, J., POZDENA, J., DALBOLA, J., LIMBERK, J. AND BOJNANSKY, V. 1954. Die ubertragung des Stolbervirus bei Tabak und Tomaten und seine Virogeographischen Beziehungen. *Phytopath. Z.* **22**: 381-416.
- BLODGETT, F. M. 1927. A potato virus on peppers. *Phytopathology* **17**: 775-82.
- BOHME, R. W. 1933. Vergleichende Untersuchungen mit Stammen des 'X' und 'Y' Virus. *Phytopath. Z.* **6**: 517-24.

- BRAWER, H. O. AND RICHARDSON, R. W. 1957. El Chile. Indicaciones generale para su cultivo. *Foll. Divulg. Secret. Agric. Mex.* **23**: 26.
- BRIEN, R. M. 1942. First supplement to 'A list of plant diseases recorded in New Zealand', *N.Z.J.Sci. Tech.* **24 A**: 62-64.
- BURNETT, F. 1947. *Report on Agriculture in Malaya for the Year 1946*. 85 pp.
- CESARONI, F. 1953. Indagini serologiche sul'mossico del Cetriolo' e sul 'fern leaf' del Pomodoro. *Ric. Sci.* **23**: 1389-98.
- CHAMBERLAIN, E. E. 1939. Cucumber mosaic (cucumis virus 1 of Smith 1937) *N.Z.J. Sci. Tech.* **21 A**: 74-90.
- . 1947. Tomato streak. *Bull. N.Z. Dep. Sci. industr. Res.* **281**: 11.
- . 1949. Tomato necrosis, a component of severe streak of tomatoes. *N.Z.J. Sci. Tech.* **31 A**: 186-97.
- CHESTER, K. S. 1936. Separation and analysis of virus strains by means of precipitin tests. *Phytopathology* **26**: 778-85.
- CHUPP, C. 1937. The effect of temperature and moisture on vegetable diseases in New York State in 1937. *Plant. Dis. Repr.* **21**: 35-41.
- CLINCH, P. E., M. LOUGHNANE, J. B. AND MURPHY, P. A. 1936. A study of the aucuba or yellow mosaic of the potato. *Sci. Proc. R. Dublin Soc.* **21**: 35-41.
- COCKERHAM, G. AND MCGHEE, T. M. R. 1953. Potato stunt disease. *Ex. Rep. Scot. Pl. Breed. Sta.* 7 pp.
- COOK, M. T. 1931. Annual Report of the Division of Botany and Plant Pathology of 1929-30. *Ann. Rep. Insulars Expr. Stat. Dept. Agric. and Labor, Puerto Rico 1929-30*: 93-109.
- COOK, A. AND ANDERSON, C. W. 1959. Multiple virus disease resistance in a strain of *Capsicum annuum*. *Phytopathology* **49**: 198-201.
- . 1960. Inheritance of resistance to potato virus Y derived from two strains of *Capsicum annuum*. *Ibid.* **50**: 73-75.
- DALE, W. T. 1943. Preliminary studies of the plant viruses of Trinidad. *Trop. Agriculture, Trin.* **20**: 198-201.
- . 1954. Sap-transmissible mosaic diseases of Solanaceous crops of Trinidad, *Ann. appl. Biol.* **41**: 240-47.
- . 1956. Virus diseases of Solanaceous crops in Trinidad. *Trop. Agriculture Trin.* **33**: 35-50.
- DANA, B. F. 1934. Occurrence of curly top in the pacific Northwest in 1934. *Plant Dis. Repr.* **18**: 168-73.
- DAVID, E. AND STÖRMER, I. 1941. *Capsicum annuum* als Testpflanze für einige Kartoffelviren. *Phytopath. Z.* **13**: 532-38.
- DEIGHTON, F. C. 1929. Report of the Mycological section. *Ann. Rept. Lands and Forests Dept. Sierra Leone for the Year 1929*, pp. 14-19.
- D'OLIVEIRA, MARIA DE L. 1940. Dois Virus de Pimento. *Agron. Lusit.* **2**: 209-33.
- DOOLITTLE, S. P. 1921. The relation of wild hosts to the overwintering of cucurbit mosaic, Abstract. *Phytopathology* **11**: 7-47.
- . 1931. *Commelina nudiflora*, a monocotyledonous host of celery mosaic. *Ibid.* **21**: 114-15.
- . 1951. Virus diseases of pepper, *Univ. Maryland Dept. Hort. Misc. Ext. Publ.* **6**: 53-55.



- DOOLITTLE AND BEECHER, F. S. 1942. A strain of tobacco mosaic causing a necrosis and shrivelling of tomato foliage. *Phytopathology* **32**: 986-94.
- AND WALKER, M. N. 1923. Cross-inoculation studies with cucurbit mosaic. *Science N. S.* **57**: 477.
- . 1925. Further studies on the overwintering and dissemination of cucurbit mosaic. *J. agric. Res.* **31**: 1-58.
- AND ZAUMEYER, W. J. 1952. A ringspot disease of peppers caused by a strain of cucumber mosaic from pepper and alfalfa. *Phytopathology*. **42**: 7.
- . 1953. A pepper ringspot caused by strains of cucumber mosaic virus from pepper and alfalfa. *Ibid.* **43**: 333-37.
- ELMER, C. H. 1957. Sweet-potato mosaic. *Ibid.* **47**: 9.
- ERWIN, A. T. 1932. The peppers. *Iowa Agric. Expt. Sta. Bull.* **293**: 119-52.
- FEIGINSAN, N. 1936. Determination of the crops susceptible to virus diseases; geographical distribution and injuriousness of virus diseases of plants. *Summ. Inst. pl. Prot. Leningr.* **1935**: 505-07. (Russian)
- FERGUSON, I. A. C. 1951. Four virus diseases of Solanaceous plants in Trinidad. *Plant Dis. Repr.* **35**: 102-05.
- FERNANDO, H. E. 1953. Research notes-insect transmission of chilli virus. *Trop. Agric.* **109**: 216.
- AND PEIRIS, J. W. L. 1957. Investigations on the chilli leaf curl complex and its control. *Ibid.* **113**: 305-23.
- GARDNER, M. W., TOMPKINS, C. M. AND THOMAS, H. R. 1937. Factors affecting the prevalence of the spotted wilt virus. *Phytopathology* **27**: 129.
- AND WHIPPLE, O. C. 1934. Spotted wilt of tomato and its transmission by thrips. *Ibid.* **24**: 1136.
- GIGANTE, R. 1955. Il 'rachitismo cespuglioso' del Pomodoro. *Bull. Staz. Pat. veg. Roma ser.* **3**: 45-56.
- GREENLEAF, W. H. 1953. Effects of tobacco etch virus on peppers (*Capsicum* spp.). *Phytopathology* **43**: 564-73.
- . 1956. Inheritance of resistance to tobacco etch virus in *Capsicum frutescens* and *Capsicum annum*. *Ibid.* **46**: 371-74.
- GUALACCINI, F. 1956. Transmissibilit  del virus produttore il mosaico den peperone mediante e la cuscuta e prove di identificazione di esso. *Boll. Staz. pat. veg. Roma* **13**: 79-101.
- HEUBERGER, J. W. 1944. Virus diseases of the California Wonder pepper in Delaware in 1943. *Phytopathology* **34**: 991-92.
- HIGGINS, B. B. 1923. The diseases of pepper. *Georgia Agric. Exp. Sta. Bull.* **141**: 48-75.
- HO, W. T. H. AND LI, L. Y. 1936. Preliminary notes on the virus diseases of some economic plants in Kwangtung Province. *Lingnan Sci. J.* **15**: 67-78.
- HOLMES, F. O. 1932. Symptoms of tobacco mosaic disease. *Contr. Boyce-Thompson Inst.* **4**: 323-57.
- . 1934. Inheritance of ability to localise tobacco mosaic virus. *Phytopathology* **24**: 984-1002.
- . 1934 a. Increases of tobacco virus in the absence of chlorophyll and light. *Ibid.* **24**: 1125-26.

- HOLMES, F. O. 1937. Inheritance of resistance to tobacco mosaic virus in pepper. *Ibid.* **27**: 637-42.
- . 1937 a. Genes affecting response of *Nicotiana tabacum* hybrids to tobacco mosaic virus. *Science, N.S.* **85**: 104-05.
- . 1948. The Filterable Viruses, Supplement 2. *Bergey's Manual of Determinative Bacteriology*, 6th Edn.
- HUSAIN, M. A. 1932. Leaf curl in cotton and other plants. *Nature, Lond.* **103**: 312.
- IKENO, S. 1930. Studien über einen eigentümlichen Fall der infectiosen Buntblatterigkeit bei *Capsicum annuum*. *Planta* **11**: 359-67.
- ISUYAMA, S. AND MISAWA, T. 1943. Stunt disease of Japanese radish. *Ann. Phytopath. Soc. Japan.* **12**: 116-30.
- JHA, A. AND RAYCHAUDHURI, S. P. 1956. Mosaic disease of chilli (*Capsicum frutescens* L.). *Indian J. agric. Sci.* **26**: 217-22.
- JOHNSON, E. M. 1930. Virus diseases of tobacco in Kentucky. *Kentucky Agric. Expt. Sta. Bull.* **306**: 289-415.
- JOHNSON, J. 1926. Mosaic diseases on differential hosts *Phytopathology* **16**: 141-49.
- KENDRICK, J. B. JR., ANDERSON, L. D. AND DICKSON, R. C. 1951. Source and seasonal spread of certain viruses in peppers in Southern California. *Ibid.* **41**: 20.
- KOHLER, E. 1940. Das Tabak-Ringspot virus als erregere einer Gelbfleckigkeit des Kartoffelaubes. *Angew. Bot.* **22**: 385-99.
- AND PANJAN, M. 1944. Das Paramosaicvirus der Tabakpflanze. *Ber. dtsh. bot. Ges.* **41**: 175-80.
- KOVACHEVSKY, I. C. 1940. Die Reisigkrankheit der paprikapflanze (*Capsicum annuum*). *Z. Pflkrakh.* **50**: 289-308.
- . 1942. Die Buntblattrigkeit der paprikapflanzen, (*Capsicum annuum*) Medicago virus 2 K. M. Smith var. typicum Black u. Price, Vorläufige Mitteilungen. *Ibid.* **52**: 533-40.
- . 1942 a. Die virus Krankheiten der Paprikapflanzen. *Arch. Bulgar. Landwirtsch. Gesellsch. Pflanzenbau.* **1**: 25-102.
- KREITLOW, K. W. AND PRICE, W. C. 1949. A new virus of Ladino clover. *Phytopathology* **39**: 517-28.
- KULKARNI, G. 1924. Mosaic and other related diseases of crops in Bombay Presidency. *Poona agric. Coll. Mag.* **16**: 6-12.
- LEYENDECKER, P. J. 1950. 1949 plant diseases survey for New Mexico. *Plant. Dis. Repr.* **34**: 39-40.
- LUTES, D. D. 1954. Inheritance of resistance to systemic mosaic infection in pepper. *Diss. Abstr.* **14**: 1900-01.
- MARIS, B. AND ROZENDAAL, A. 1956. Enkele proven met stammen van het X-en het aucubabontvirus van de Aardappel. *Tijdschr. Plziekt.* **62**: 12-18.
- MARTIN, W. H. 1930. Plant Pathology. *Fifty-first Ann. Rept. New Jersey Agric. Expt. Stat. Year ending June 30, 1930*: 44-51, 235-54.
- McKEEN C. D. 1953. Tobacco etch on peppers in South-western Ontario. *Proc. Canad. phytopath. Soc.* **20**: 19.

- McKEEN, C. D. 1954. Tobacco etch in peppers in Southern Ontario. *Canad. J. Bot.* **32**: 96-100.
- MCKINNEY, H. H. 1929. Mosaic diseases in Canary Islands, West Africa and Gibraltar. *J. agric. Res.* **39**: 557-58.
- . 1952. Two strains of tobacco mosaic virus one of which is seed-borne in etch immune pungent peppers. *Plant Dis. Repr.* **36**: 184-87.
- McLEAN, A. P. D. 1935. The bunchy top disease of the tomato. Host range of the bunchy top virus. *Fmg. in S. Afr.* **10**: 302-03.
- McRAE, W. 1924. Economic Botany. Part III. Mycology. *Ann. Rept. Board of Sci. Advice, India* **1922-23**: 31-35.
- . 1929. India: New diseases reported during the year 1928. *Int. Bull. Pl. Prot.* **3**: 21-22.
- MENZIES, J. D. AND GIDDINGS, N. J. 1953. Identity of potato curly top and green dwarf. *Phytopathology.* **43**: 684-86.
- MILLER, P. M. AND THORNBERRY, H. H. 1958. A new viral disease of tomato and pepper. *Ibid.* **48**: 665-69.
- MULLER, A. S. 1936. Brazil: New plant diseases reported in the state of Minas Geraes during 1936. *Int. Bull. Pl. Prot.* **11**: 174-75.
- NAKATA, K. AND TAKIMOTO, S. 1940. A ring strain of tobacco common mosaic found on the pepper. *Bull. Sci. Fak. terk Kyusu Univ.* **9**: 178-79.
- NARIANI, T. K. AND SASTRY, K. S. M. 1958. Two additional vectors of chilli mosaic virus. *Indian Phytopath.* **11**: 193-94.
- NEWTON, W. 1953. Two new sap-transmissible virus diseases of chilli. *Trop. Agric.* **109**: 217.
- NOORDAM, D. 1952. Lycopersicum virus 3 (tomato spotted wilt.) bij enkele bolemis terij gewassen. *Tijdschr. Plziekt.* **58**: 89-96.
- OSWALD, J. W. 1950. A strain of alfalfa mosaic virus causing vine and tuber necrosis in potato. *Phytopathology* **40**: 973-91.
- PALM, B. T. 1923. Verslag van het Deli proefstation over i Juli 1922-30 Juni 1923, *Meded. Deli-Proefst. Sumatra*, Ser. 2: **29**: 1-41.
- . 1932. Pflanzenkrankheiten aus Guatemala. *Z. Pflkrankh.* **42**: 11-17.
- AND JOACHEMS, S. C. J. 1924. De voornamste Tabakziekten in Deli in Verband met de begoring der Tabaksgronden. *Bull. Deli-Proefst. Sumatra.* **20**: 1-64.
- PANJAN, M. AND PRPIC, Z. 1955. O jeanoj varijanti mozaika Duhana izoliaranog iz paprike. *Arh. poljopr. Nauk.* **8**: 3-10.
- PARK, M. 1932. Report on the work of the Mycological division. *Ceylon Adm. Repts. Director of Agric. for* **1931**: D. 103-11.
- . 1935. Report of the work of the Mycological Division. *Ibid.* **1934**: D 124-31.
- PEIRIS, J. W. L. 1953. Chilli leaf curl complex. *Trop. Agric.* **109**: 201-02.
- PEREZ, J. E. AND ADSUAR, J. 1955. Antigenic properties between Puerto Rican pepper mosaic virus and a strain of potato virus Y. *J. Agric. Univ. P. R.* **39**: 165-67.
- PIRONE, P. P. 1935. Spotted wilt of tomatoes and peppers in New York. *Plant. Dis. Repr.* **19**: 244.



- PLOPER, J. 1948. La 'peste nigra' del Tomate y 'peste blanca' del Pimiento características forma de lucha para disminuir los danos. *Circ. Estac. exp. agric. Tucuman* **141**: 3.
- PORTER, D. R. 1935. Insect transmission, host range and field spread of potato calico, *Hilgardia* **9**: 383-94.
- PRICE, W. C. 1935. Classification of southern celery mosaic virus. *Phytopathology* **25**: 947-54.
- PURDY, H. A. 1929. Immunological reactions with tobacco mosaic virus. *J. exptl. Med.* **49**: 919-35.
- QUANTZ, L. 1956. Zum Nachweis des Luzernmosaicvirus in Deutschland und Italien. *Phytopath. Z.* **28**: 83-103.
- RIOLLANO, A., ADSUAR, J. AND RODRIGUEZ, A. 1948. Breeding peppers resistant to Puerto Rican type of mosaic. *Proc. Amer. Soc. hort. Sci.* **51**: 415-16.
- RISCHKOW, V. L. AND KARATCHEVSKY, I. K. 1934. Über die Entstehung von 'Fern-leaf' bei Tomaten. *Phytopath. Z.* **7**: 231-44.
- ROLAND, G. 1950. Etude preliminaire sur les variantes du virus X (*Solanum virus* I, Orton), *Parasitica* **6**: 51-62.
- ROQUE, A. AND ADSUAR, J. 1939. *Ann. Rept. Agric. Expt. Stat., Rio Piedras, Puerto Rico* **1938-39**: 99.
- . 1941. Studies on the mosaic of peppers (*Capsicum frutescens*) in Puerto Rico. *J. Agric. Univ. P.R.* **25**: 40-50.
- RYJKOFF, V. L. AND KARATCHEVSKY, I. K. 1934. Experiments on the artificial transmission of virus diseases of the tomato. ex. *Virus diseases of Plants in the Crimea and the Ukraine*, State Publ. Office of the Crimea. (Russian)
- SAKIMURA, K. 1953. Potato Virus Y in Hawaii. *Phytopathology* **43**: 217.
- SALAMAN, R. W. 1938. The potato virus X: Its strains and reactions, *Phil. Trans., Ser. B* **229**: 137-217.
- SAMSON, R. W. AND IMLE, E. P. 1942. A ringspot type of virus disease of tomato *Phytopathology*. **32**: 1037-47.
- SARDINA, J. R. 1940. Acerca de la 'blanqueta' del Pimiento (nota preventiva). *Bol. Pat. veg. Ent. Agric. Madr.* **9**: 1-8.
- SAVULESCU, T., SANDU-VILLE, C., RAYSS, T. AND ALEXANDRI, V. 1934. L'etat phytosanitaire en Roumanie au cours de l'annee 1932-33. *Inst. Cerc. Agron. al. Roumaniei* **12**: 93.
- SCHULTZ, E. S., CLARK, C. F., STEVENSON, F. J. AND RALEIGH, W. P. 1937. Resistance of the potato to latent mosaic. *Amer. Potato. J.* **14**: 124-27.
- SEVERIN, H. H. P. 1929. Additional host plants of curly top. *Hilgardia*. **3**: 595-627.
- SHEPARD, E. F. S. 1938. Botanical Division, Ann. Rept. *Mauritius Dept. Agric. for the Year.* **1928**: 124-27.
- SIMONS, J. N. 1955. *Ann. Rept. Agric. Res. Stat. Florida for Year ending June 30, 1954*.
- . 1955 a. Some plant vector-virus relationships of Southern celery mosaic virus. *Phytopathology*. **45**: 217-19.
- . 1956. The pepper veinbanding mosaic virus in the Everglades area of South Florida. *Ibid.* **46**: 53-57.

- SIMONS, J. N. 1957. Effects of insecticides and physical barriers on field spread of pepper vein-banding mosaic virus. *Phytopathology* **47**: 145-50.
- . 1957a. Three strains of cucumber mosaic virus affecting bell pepper in Everglades area of South Florida. *Ibid.* **47**: 265-68.
- . 1958. Titres of three non-persistent aphid-borne viruses affecting pepper in South Florida. *Ibid.* **48**: 265-68.
- . 1959. Potato virus Y appears in additional areas of tomato and pepper production in South Florida. *Plant Dis. Repr.* **43**: 710-11.
- SMITH, K. M. 1932. Studies on plant virus diseases. XI. Further experiments with a ringspot virus; its identification with spotted wilt of tomato. *Ann. appl. Biol.* **19**: 305-30.
- . 1957. *A Text-Book of Plant Virus Diseases*. 2nd Edn., Boston, Little, Brown Co. 652 pp.
- SORIANO, S. 1932. Nota sobre algunas enfermedades de los vegetales producidas por 'virus' en la Republica Argentina. *Physis. (Rev. Soc. Argentina Cien. Nat.)* **11**: 87-90.
- STOVER, W. G. AND VERMILLION, M. T. 1933. Some experiments with a yellow mosaic of tomato. *Phytopathology* **23**: 34.
- STUBBS, I. L. 1947. A destructive vascular wilt virus disease of board bean (*Vicia faba* L.) in Victoria. *J. Dept. Agric. Vict.* **45**: 323-32.
- . 1952. Further host range and transmission studies with a virus disease of carrot endemic to Australia. *Aust. J. Sci. Res. Ser. B*, **5**: 399-408.
- SU, M. T. 1936. Report of the Mycologist, Burma, Mandalay, for the year ending 31st March 1936, 5 pp.
- SUKHOV, K. S. AND VOIK, A. M. 1946. Woodiness of Solanaceae and the means of combating it. *All Union Sci. Res. Inst. of the Canning Industry*, 32 pp. (Russian)
- . 1947. The virus of stolbur the causal agent of the mass wilting of peppers, egg plant and potato in the South (Russian). *Dokl. Akad. Nauk. SSSR, N.S.* **58**: 319-21.
- SÜTIC, D. 1959. Die Rolle des Paprikasamens bei der Virusübertragung. *Phytopath. Z.* **36**: 84-93.
- SZIRMAI, J. 1937-40. Abbau des Gewurzpaprikas einleitende Viruskrankeheit gennant "Ujhituseg," *Landw. Versuchstat. Nagybakta (Ungarn)* 127-33.
- . 1948. Virusbetegsegek terjedese a vetomag utjan. Kulonleny az Agrartud Egyet. *Kert-es Szologazd tud. Kar Kozl.* **12**: 1-18. (Hungarian)
- THUNG, T. H. 1939. Phytopathologische waarnemingen. *Meded. Proefst. vorstentl.* **87**: 23-46.
- TRAVERSI, B. A. 1949. Estudio inicial sobre una enfermedad de Girasol (*Helianthus annuus* L.) en Argentina. *Rev. Invest. agric. B. Aires* **3**: 345-51.
- TU, C. 1933. Notes on diseases of economic plants in South China. *Lingnan Sci. J.* **11**: 489-504.
- UPPAL, B. N. 1929. India: mosaic disease of chillies (*Capsicum annum*) in the Bombay Presidency. *Int. Bull. Pl. Prot.* **3**: 99.
- . 1929a. Appendix M. Summary of the work done under the Plant Pathologist to Government, Bombay Presidency, Poona, for the year 1927-28. *Ann. Rept. Dept. Agric. Bombay Prescy., for 1927-28*: 203-06.

- UPPAL, B. N. 1930. Appendix M. Summary of work done under the Plant Pathologist to Government, Bombay Presidency, Poona, for the year 1928-29. *Ibid.* 1928-29: 199.
- VAN DER MEER, J. H. H. 1932. A study of the virus from apparently healthy potato variety "Green Mountain". *Zentralbl. Bakt., Abt. (2)* 87: 240-62.
- VAN HALL, C. J. 1924. Ziekten en plagen der culturgewassen in Nederlandschen Indie in 1923. *Meded. Inst. Voor Plziekt.* 14: 47.
- VAN SCHREVEN, D. A. 1935. Virusziekten van den Tomat, *Tijdschr. Plziekt* 41: 261-300.
- . 1948. Onderzoekigen met betrekking tot enkele plagen en ziekten van Vorstlandes Tabak. *Ibid.* 54: 149-74.
- VASUDEVA, R. S. 1954. Report of the Division of Mycology and Plant Pathology. *Sci. Rept. agric. Res. Inst., New Delhi* 1952-53: 79-89.
- WEBER, G. F. 1932. Diseases of peppers in Florida. *Fla. agric. Expt. Sta. Bull.* 244: 46.
- WELLMAN, F. L. 1934. Identification of celery virus I, cause of southern celery mosaic. *Phytopathology* 24: 695-725.
- . 1934 a. Infection of *Zea mays* and various other Gramineae by the celery virus in Florida. *Ibid.* 24: 1035-37.
- . 1935. Dissemination of southern celery mosaic virus on vegetable crops in Florida. *Ibid.* 25: 289-308.
- . 1935 a. The host range of southern celery mosaic virus. *Ibid.* 25: 377-404.
- WENZL, H. 1956. Die stolbur-viruskrankheit in Osterreich. *Pflanzenarzt.* 9: 4-7.
- WOODS, M. V. AND ECK, R. V. 1948. Nuclear inclusions produced by a strain of tobacco mosaic virus. *Phytopathology* 38: 852.
- ZABALA, S. AND DELLE COSTE, A. C. 1947. La presencia del mosaico comun-del Tobacco en los cultivos de Pimiento y tomate. *Publ. misc. Minist. Agric. B. Aires.* Ser. A. 28: 8.
- AND —. 1947 a. Identification del 'polville' del Tobacco con uno de los mosaico del Pimiento. *Rev. Argent. Agron.* 13: 167-80.



# ORGANOGRAPHY AND FLORAL ANATOMY OF SOME MEMBERS OF THE RHAMNACEAE

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THE Rhamnaceae is represented by 40 genera and 550 species distributed in the tropics and temperate regions (Lawrence, 1959). The flowers of the family exhibit several interesting morphological peculiarities such as antipetalous stamens, very conspicuous disc, and a change from hypogyny to epigyny, bisexuality to unisexuality, dichlamydy to monochlamydy, etc.

The earliest account on the floral anatomy of the family is by Saunders (1939) on *Rhamnus*. Recently Prichard (1955) studied the vascular anatomy of the flower of 12 species. Reference to these works will be made at appropriate places. The present account deals with the organography and floral anatomy of *Zizyphus xylopyra* Willd., *Z. nummularia* W. & A., *Z. mauritiana* Lamk., *Z. hysudrica* Park., *Z. funiculosa* Ham., *Z. oenoplia* Mill., *Helinus lanceolatus* Brand. and *Ventilago madraspatana* Gaertn.

## MATERIALS AND METHODS

*Z. xylopyra*, *Z. nummularia* and *Z. mauritiana* were collected from Pilani and its neighbourhood and fixed in formalin-acetic-alcohol. Only herbarium materials were available for the rest of the species and they were treated with three per cent. potassium hydroxide at 50° C. for 12 hours. Later they were washed in tap-water for an equal length of time and fixed in formalin-acetic-alcohol. Dehydration and embedding were followed in the usual manner (Johansen, 1940). Sections cut at 10-18 microns thickness were stained with safranin and fast green as well as erythrosin and crystal violet combinations.

## OBSERVATIONS

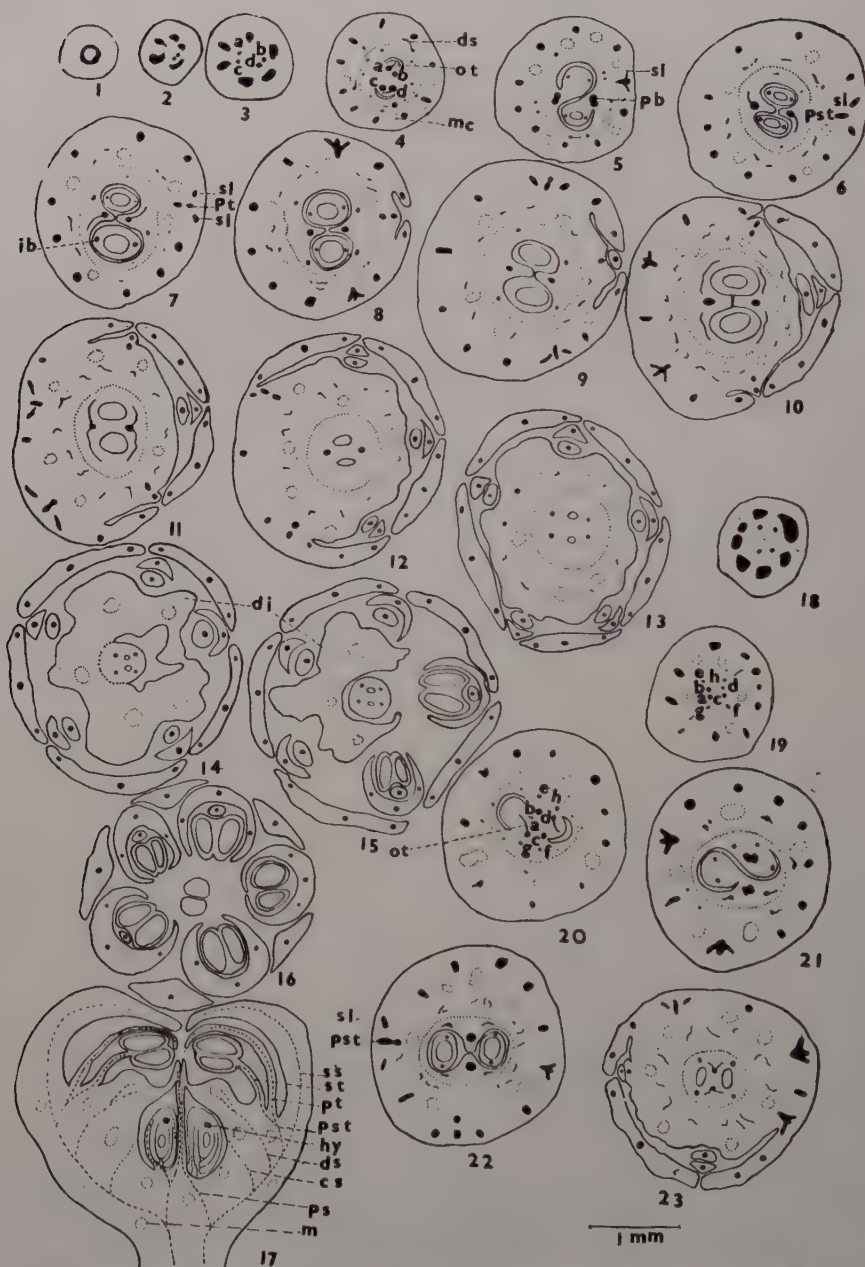
*Zizyphus*.—The species of *Zizyphus* studied exhibit a general uniformity in the organography and vascular anatomy of the flower that makes a generalized description possible. However, variations do occur and will be referred to wherever necessary.

The flowers are arranged in sessile (*Z. nummularia* and *Z. mauritiana*) or sub-sessile (*Z. oenoplia*) or peduncled (*Z. xylopyra* and *Z. hysudrica*, axillary cymose clusters. They are pentamerous, actinomorphic, dichlamydeous, perigynous and perfect. The valvate sepals are glabrous)

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TEXT-FIGS. 1-23. Figs. 1-16. *Zizyphus xylopyra*. Serial transections from pedicel upwards. Figs. 17-23. *Z. mauritiana*. Serial transections from pedicel upwards. (cs, carpellary supply; di, disc; ds, disc supply; hy, hypostase; ib, integumentary bundle; mc, mucilage cavity; ot, ovular trace; pb, placental bundle; pst, petal-stamen trace; ps, placental supply; pt, petal trace; sl, sepal lateral; ss, sepal supply; st, staminal trace).

keeled within, and slightly united at the base. They are covered by brown or greyish tomentum. The petals are deflexed, concave, spathulate and cucullate. The glandular disc which is five angled in *Z. xylopyra*, and ten-lobed in the rest of the species is an outstanding feature of the flower. The antipetalous stamens have ditheous introrse anthers. In the younger stages the anther wall consists of tapetum, two middle layers, an endothecium and epidermis. The tapetal cells are uninucleate at first but become two to three nucleate. Further behaviour conforms to the secretory type. The middle layers are ephemeral. Fibrous thickenings appear in the endothecial cells at maturity. The semi-inferior ovary is bilocular at the base and the apex (Text-Figs. 4, 11). In the centre the placentas slightly recede (Text-Figs. 5-10, 21, 22). Each locule bears a single, anatropous, bitegmic, crassinucellate ovule on sub-basal placenta (Text-Fig. 17). The ovary is continued into a bifid style (Text-Fig. 16) terminating in glandular stigmas. There are two narrow stylar canals extending up to the middle of the style (Text-Figs. 12-14). In some cases only one canal was seen in *Z. nummularia* and *Z. hysudrica*. It is surrounded by glandular cells. Mucilaginous cavities are present in all the floral parts, particularly in the receptacular cortex and the disc. They are formed by the disintegration of cells. Tannin and sphaerocrystals are abundant in the receptacle and the disc.

In the pedicel there is an undissected siphonostele (Text-Fig. 1). In the receptacle the stele expands and from it diverge out five traces which while moving to the periphery divide radially into two each, forming ten traces (Text-Figs. 2-4). These traces give a small branch each to supply the wall of the ovary and at a higher level give a whorl of traces to the disc (Text-Figs. 4-7). Five of the traces form the midribs of sepals (Text-Figs. 5-8) and the other traces divide into three branches (Text-Figs. 5-10, 21-23, 28). The lateral branches ultimately become the marginal bundles of the sepals. The median branch undergoes a tangential division to form two traces. The outer of the two forms the supply of the petal and the inner enters the filament of the stamen (Text-Figs. 6-10). In the higher regions the petal shows three bundles in transection.

Four bundles, marked *a*, *b*, *c* and *d* in Text-Figs. 3-4, are left in the centre. At first they are normally oriented but in their upward course they become inverted and function as ventral bundles. In one of the flowers examined only two bundles were left in the centre which a little above divide to form four bundles. Here the ovary is bilocular and the ovules are borne diagonally opposite to each other. Of the four bundles *a* and *d* supply one ovule each (Text-Fig. 4). After the ovular supply has been given out the bundles *a* and *c*, and *b* and *d* fuse to form two inversely oriented placental bundles on the septal radii (Text-Figs. 5, 6). In some members of the related Vitaceae also the placental bundles are formed after the ovular supplies have been given out (Nair and Mani, 1960). At this level the placentas slightly recede to the periphery (Text-Figs. 5, 6). Closely above, two branches diverge out successively from each of the placental bundles and extend upward



in the carpellary wall and ultimately fade out in the higher regions (Text-Figs. 6-11). In the style, only the septal bundles, which might sometimes divide to form four bundles, continue for some distance (Text-Figs. 13-15).

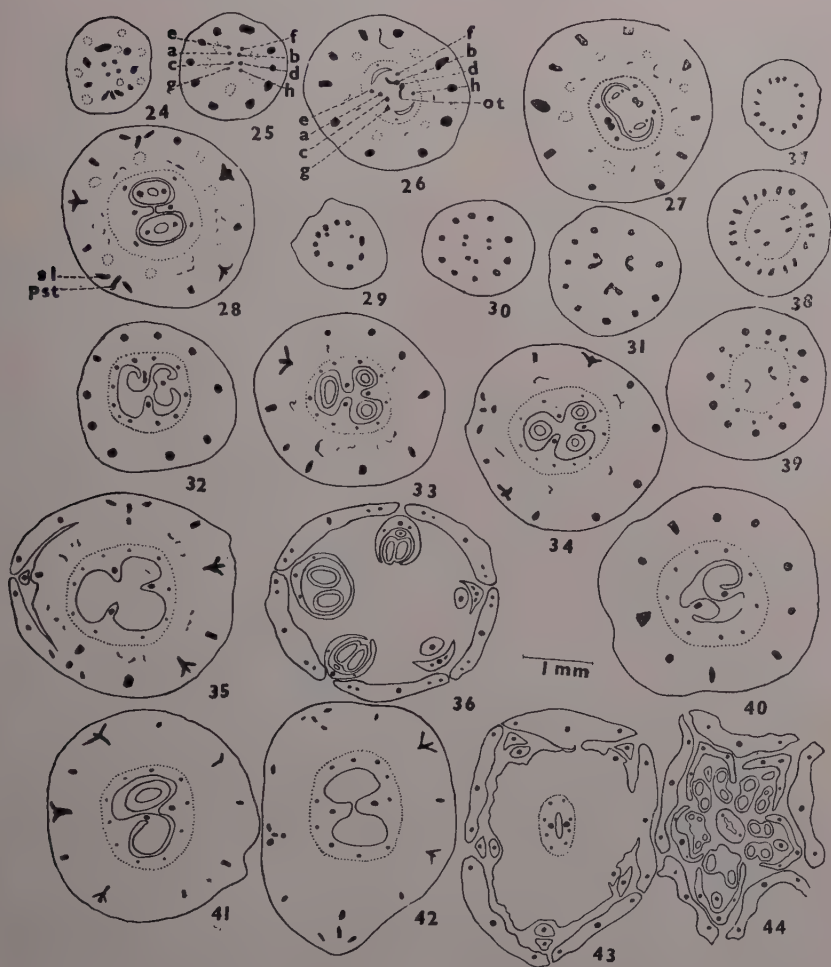
In *Z. mauritiana* the four bundles left in the centre as usual divide to form eight bundles (Text-Figs. 18-20). A similar feature was observed in one of the flowers of *Z. hysudrica* (Text-Figs. 24-26). In *Z. hysudrica*, unlike *Z. mauritiana*, the ovules are arranged on the same side instead of the usual diagonally opposite condition (Text-Figs. 26, 27). After the ovular supply (Text-Figs. 20, 26) the bundles *a* and *c*, and *b* and *d*, unite to form the placental strands. Rest of the bundles diverge out and supply the carpellary wall. In *Z. mauritiana* tricarpeillary and tetracarpeillary ovaries were observed, in which case the additional bundles, before diverging to the ovary wall, fuse in pairs to supply the additional placentas.

*Helinus*.—The pentamerous flowers are borne on umbellate peduncles. The disc is very conspicuous and may be described as epigynous. The ovary is tricarpeillary and trilocular at the base becoming unilocular by the receding of the placentas (Text-Figs. 32-34). Each carpel bears a single ovule. Two ovules of adjacent carpels are attached to one placenta while the other ovule was attached to one of the remaining placentas. The third placenta had no ovule in all the flowers examined (Text-Fig. 32). The ovary terminates in a style with three stigmas.

Pedicle contains ten vascular bundles (Text-Fig. 29). The bundles expand in the receptacle and from them diverge inward six traces (Text-Figs. 30, 31) which fuse in pairs and form inversely oriented placental bundles on septal radii (Text-Fig. 31). The loculi appear close above this level. In the higher regions one of the placental bundles supply two ovules of the adjacent carpels and another supply the other ovule and the third does not take part in the ovular supply (Text-Fig. 32). After the ovular supply had been given out the placental bundles fuse with the carpellary supply and continue for some distance in the style.

The remaining vascular tissue continues for some distance in the floral tube and divide tangentially to form two rings of vascular bundles (Text-Fig. 32). At this level the ovary is unilocular. The inner ring supplies the ovary wall and shows some anastomosis. Five of the outer ring of bundles, after giving a trace each to the disc, form the midribs of the sepals. The remaining bundles divide to form the sepal laterals, petal traces and staminal supply as in *Zizyphus* (Text-Figs. 32-36).

*Ventilago*.—The small flowers are arranged in spikes. The external morphology and vascular anatomy of the flower do not show much variation from that of *Helinus lanceolatus* (Text-Figs. 37-44). The chief points of divergence are: (a) pedicle contains a ring of more than ten bundles (Text-Fig. 37), (b) the ovary is bicarpeillary with a single ovule in each carpel, (c) the ovules are arranged on diagonally opposite margins of the placentas (Text-Figs. 40-41), (d) the style is hairy at the basal part and is provided with prominent styler canal.



TEXT-FIGS. 24-44. Figs. 24-28. *Zizyphus hysudrica*. Serial transections from pedicel upwards. Figs. 29-36. *Helinus lanceolatus*. Serial transections from pedicel upwards. Figs. 37-44. *Ventilago madraspatana*. Serial transections from pedicel upwards. (ot, ovular trace; sl, sepal lateral; pst, petal-stamen trace).

## DISCUSSION

The organography and vascular anatomy of the species studied manifest a general uniformity. There is high degree of adnation between members of the adjacent whorls of floral appendages coupled with the fusion of their vascular supply. In all cases the lateral traces of adjacent sepals, the petal trace, and the staminal trace are fused together becoming separated into their respective components only in the higher regions. The carpellary and the disc supplies are also fused

with the supplies to the other floral appendages to a greater or lesser extent. A more or less similar condition is reported in the allied family Vitaceae (Kashyap, 1957; Nair and Nambisan, 1957; Nair and Mani, 1960). In all cases the first set of traces demarcated from the receptacular stele are the ventrals which clearly indicates the perigynous nature of the flower. It may be regarded that perigynous condition is the result of adnation and cohesion of the floral members and their vascular supply.

Generally the successive whorls of floral organs alternate with each other. This rule is violated in the Rhamnaceae because of the presence of antipetalous stamens. Prichard (1955) thinks that the family is obdiplostemonous and the inner whorl of stamens have got modified along with the base of the perianth to form the conspicuous disc. The findings in the present study support such an inference.

The gynoecium is supplied by a larger number of bundles than the usual dorsals and ventrals. This may probably indicate their derivation from a multicarpellary state. The variability in the number of carpels observed in the present study is significant in this connection.

The placentation in this family had been described basal in the taxonomic literature (Bentham and Hooker, 1862; Engler and Prantl, 1889; Rendle, 1952; Warming and Potter, 1932; Gundersen, 1950; Lawrence, 1959). According to Puri's (1952) definitions, *Helinus* and *Ventilago* have parietal placentation (see also Prichard, 1955). In most members of *Zizyphus* four bundles swing inward and fuse in pairs to form inversely oriented bundles in septal radii. Just before fusion the diagonally placed bundles supply an ovule each. The ovules are attached towards the base, laterally, indicating that the basal condition is derived from parietal and therefore the placentation in *Zizyphus* is better described as sub-basal (see Puri, 1952).

It may be recalled that in *Z. mauritiana* and some times in *Z. hysudrica* four bundles swing inward and divide to form eight bundles. Out of these only four fuse in pairs to form the placental bundles. That the additional bundles are vestigial ventrals of the carpels lost in evolution is indicated by the behaviour of these bundles in the tetracarpellary gynoecium of *Z. mauritiana*.

The placental bundles are inversely oriented in all cases. This may be due to the derivation from an axile placentation as envisaged by Puri (1952).

Of the two margins of each carpel only one retains fertility. In *Zizyphus* species the ovules are borne diagonally opposite to each other. In one of the flowers of *Z. hysudrica* both the ovules were borne on the same side. More or less similar variations in the fertility of carpellary margins are reported in other members of the family by Prichard (1955). These findings show that originally all the carpellary margins were fertile. In most of the present-day forms only the diagonally opposite margins retain ovule-bearing function. This might be true for *Ventilago* also.



## TAXONOMIC CONSIDERATIONS

The systematic position of the Rhamnaceae is controversial. Bentham and Hooker (1862) placed it in the Celastrales in between the Stackhousiaceae and the Vitaceae. Bessey (1915), and Warming and Potter (1932) also included it under the Celastrales but they regarded the family to be related to the Celastraceae and the Vitaceae. Engler and Prantl (1889), Hallier (1905), Wettstein (1935), Rendle (1952), Lawrence (1959), Gundersen (1950), and Hutchinson (1959) have treated the Rhamnaceae and the Vitaceae together in a separate order the Rhamnales.

As shown by Narang (1953) the Rhamnaceae and the Stackhousiaceae have no remarkable similarity while the differences are many.

In trying to compare the Rhamnaceae with the Celastraceae one difficulty is at hand due to our fragmentary knowledge of the various aspects of floral morphology of the Celastraceae. According to Willis (1956) the Rhamnaceae approaches the Celastraceae, the only difference being the antisepalous stamens in the latter family. Prichard (1955) thinks that the two families have arisen from a hypothetical ancestor having obdiplostemonous stamens. The loss of antisealous stamens resulted in the Rhamnaceae while the disappearance of the antipetalous whorl produced the Celastraceae. It must be noted that floral-anatomically there is very little in common between the two families (see Berkley, 1953). Further the embryological and palynological data do not support any relationship between the two families (see Mauritzon, 1936; Kajale, 1944; Arora, 1953; Erdtman, 1952).

Regarding the affinities of the Rhamnaceae with the Vitaceae it is to be noted that we come across an imposing array of similarities. The cymose inflorescence, pentamerous or tetramerous flowers, valvate perianth parts, antipetalous stamens, conjoint petal stamen trace, conspicuous intrastaminal disc, and basically parietal placentation derived from axile condition are some of the important characters that bind the two families together. Palynologically these two families are similar (see Erdtman, 1952). To these may be added some of the embryological features common to both the families such as anther wall consisting of five layers of cells, multinucleate secretory tapetum, pollen grains with smooth exine and three germ pores, bitegmic crassinucellate anatropous ovule with downwardly directed micropyle, thick integuments, a nucellar cap, a well-developed hypostase, multicellular ovular archesporium and free nuclear endosperm (see Dolchar, 1941; Kajale, 1944; Srinivasachar, 1940; Mulay, Nair and Sastry, 1953; Nair and Parasuraman, 1954; Nair and Nambisan, 1957; Nair and Suri, 1957; Kashyap, 1956, 1958). The major embryological difference is the Allium type of embryo-sac in some members of the Rhamnaceae. But this may be a later derivation from the monosporic type present in both the families. In view of these similarities the treatment of the two families together seems justified.

## SUMMARY

The present work deals with the organography and floral anatomy of *Zizyphus xylopyra*, *Z. nummularia*, *Z. hysudrica*, *Z. mauritiana*, *Z. oenoplia*, *Z. funiculosa*, *Helinus lanceolatus* and *Ventilago madraspatana*. The flowers are bisexual, actinomorphic, pentamerous, dichlamydeous, with antipetalous stamens having introrse anthers, and a 2-4 carpellary ovary sunk in the fleshy disc and having one anatropous ovule for each carpel.

The supplies to the petals and stamens are fused with the lateral traces of the adjacent sepals. The carpellary and disc supplies are also fused to the perianth traces.

The gynoecium is considered to be derived from a multicarpellary state. The placentation in *Helinus* and *Ventilago* is parietal while in *Zizyphus* it is sub-basal.

The family is considered to be derived from obdiplostemonous ancestors and the inner whorl of stamens are regarded to have modified along with the base of the perianth to form the disc.

The perigynous condition is resulted by the cohesion and adnation of the various floral parts and their vascular supply.

The taxonomic position of the family is discussed in the light of available information. The treatment of the Rhamnaceae and the Vitaceae together seems justified.

## REFERENCES

- ARORA, N. 1953. The embryology of *Zizyphus rotundifolia* Lamk. *Phytomorphology* 3: 88-98.
- BERKLEY, E. 1953. Morphological studies in the Celastraceae. *J. Elisha Mitchell Sci. Soc.* 69: 185-206.
- BESSEY, C. E. 1915. The phylogenetic taxonomy of flowering plants. *Ann. Mo. bot. Gdn* 2: 109-64.
- BENTHAM, G. AND HOOKER, J. D. 1862. *Genera Plantarum*, London.
- DOLCHER, T. 1941. Ricerche embriologiche sulla familia della Rhamnaceae. *Nuovo G. bot. ital.* 54: 1-26.
- ENGLER, A. AND PRANTL, K. 1889. *Die natürlichen Pflanzen familien*, Leipzig.
- ERDTMAN, G. 1952. *Pollen Morphology and Plant Taxonomy*, Mass.
- GUNDERSEN, A. 1950. *Families of Dicotyledons*, Mass.
- HALLIER, H. 1905. Provisional scheme of the natural (phylogenetic) system of flowering plants. *New phytol.* 4: 101-62.
- HUTCHINSON, J. 1959. *The Families of Flowering Plants*. I. *Dicotyledons*. London.
- JOHANSEN, D. A. 1940. *Plant Microtechnique*, New York.
- KAJALE, L. B. 1944. A contribution to the life-history of *Zizyphus jujuba* Lamk, *Proc. nat. Inst. Sci. India* 10: 387-97.

- KASHYAP, G. 1955. Studies in the family Vitaceae. I. Floral morphology of *Vitis trifolia* Linn. *J. Agra Univ. Res.* 4: 777-84.
- . 1957. Studies in the family vitaceae. II. Floral anatomy of *Vitis trifolia* Linn., *V. latifolia* Roxb., and *V. himalayana* Brandis. *J. Indian bot. Soc.* 36: 317-23.
- . 1958. Studies in the family Vitaceae. III. Floral morphology of *Vitis trifolia* Linn., *V. latifolia* Roxb., and *V. himalayana* Brandis. *J. Indian bot. Soc.* 37: 240-48.
- Lawrence, G. H. M. 1959. *Taxonomy of Vascular Plants*. New York.
- MAURITZON, J. 1936. Zur Embryologie und systematischen Abgrenzung der Reihen Terebinthales und Celastrales. *Bot. Notiser* 161-212.
- MULAY, B. N., NAIR, N. C. AND SASTRY, M. S. R. 1953. Contribution to the Embryology of Vitaceae. I. Male and female gametophyte of *Vitis pedata*. *Proc. Rajasthan Acad. Sci.* 4: 17-28.
- NAIR, N. C. AND PARASURAMAN, V. 1954. Gametophytes of *Vitis pallida* (W. and A). *Curr. sci. India* 23: 163-64.
- AND NAMBIAN, P. N. N. 1957. Contribution to the floral morphology and embryology of *Leea sambucina* Willd. *Bot. Notiser* 110: 160-72.
- AND SURI, P. L. 1957. Contribution to the embryology of *Vitis latifolia* Roxb. (Syn. *Cissus latifolia* Vahl.) *Sci. & Cult.* 22: 397-89.
- AND MANI, K. V. 1960. The organography and vascular anatomy of the flower of some species of Vitaceae. *Phytomorphology* 10: 128-144.
- NARANG, N. 1953. The life-history of *Stackhousia linariaefolia* A. Cunn. with a discussion on its systematic position. *Phytomorphology* 3: 485-93.
- PRICHARD, E. C. 1955. Morphological studies in Rhamnaceae. *J. Elisha Mitchell Sci. Soc.* 71: 82-106.
- PURI, V. 1952. Placentation in Angiosperms. *Bot. Rev.* 18: 603-51.
- RENDLE, A. B. 1952. *The Classification of Flowering Plants*. II. Dicotyledons. Cambridge.
- SAUNDERS, E. R. 1939. *Floral Morphology—A New Outlook with Special Reference to the Interpretation of the Gynoecium*. Cambridge.
- SRINIVASACHAR, D. 1940. Embryological studies of some members of Rhamnaceae. *Proc. Indian Acad. Sci.* 11 B: 107-15.
- WARMING, M. E. AND POTTER, M. C. 1932. *A Handbook of Systematic Botany*. London.
- WETTSTEIN, R. 1935. *Handbuch der Systematischen Botanik*. Leipzig.
- WILLIS, J. C. 1956. *A Dictionary of the Flowering Plants and Ferns*. Cambridge.



# A NEW SPECIES OF *ROYA* (*R. KUMAOENSE* SP. NOV.) FROM NAINI TAL, INDIA

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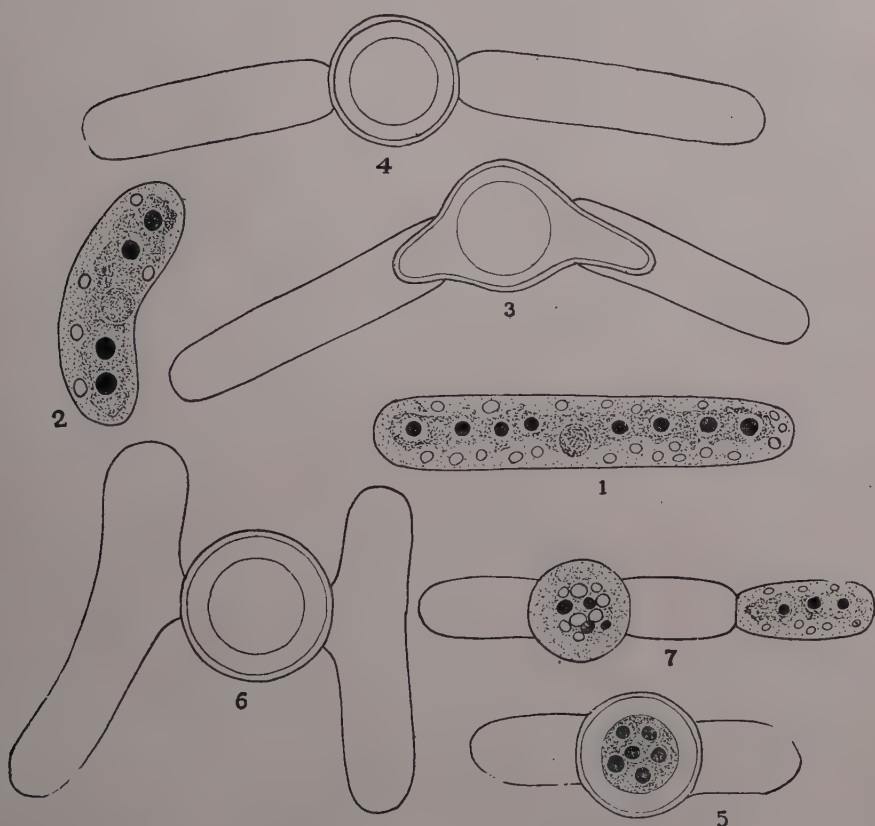
THE genus *Roya*, a saccoderm desmid of rare occurrence, was established by West and West in 1896 on the type species *R. obtusa*. Its generic attributes were later amended by Hedgetts (1920). West and West (1904, 1923) in their illuminating monographs on British Desmidiaceae enlist four species of *Roya*, viz., *R. obtusa*, *R. cambrica*, *R. pseudoclosterium* and *R. anglica*. A survey of the literatures indicates that these species have been recorded mainly from Europe and United States of America. This genus, so far the writer is aware, has been recorded only from Siberia in Asia. During the course of his studies the author came across an interesting form of this rare genus in Naini Tal. The luxuriant growth of the alga in this locality provided an opportunity for the study of its life-history and which is described in detail below.

## MATERIAL AND METHODS

This interesting alga was collected in the month of August 1958 from a dripping rock near Ramsay Hospital in Naini Tal (India) at an altitude of about 6,600' above sea-level. The organism grows in mucilaginous masses often mixed with isolated cells of *Chroococcus* and *Calothrix* species. It appears whitish-pale in colour, but becomes slightly dull at the time of reproduction. The alga was collected periodically at an interval of three-four days and was always studied in living condition. All the illustrations and microphotographs presented herein were prepared from living specimens.

## OBSERVATIONS

*A. Cell structure.*—A thorough study of the alga reveals that it contains cells in all stages of development. The mature vegetative cells are usually cylindrical with rounded poles (Text-Fig. 1; Plate I, Fig. 3 a) and measure  $97.8-128.8\mu$  long and  $15.6-19.5\mu$  broad. The cells are usually straight, but in certain cases they are slightly arcuate (Text-Fig. 2). Mostly cells are of uniform diameter throughout their length (Plate I, Fig. 3 a), but in some cases the cells exhibit gradual tapering from pole to pole (Text-Fig. 1; Plate I, Fig. 4 b). Each cell contains a single axile chloroplast which extends to the entire length of the cell (Text-Figs. 1, 2; Plate I, Fig. 3 a). The chloroplast bears a median series of 4-14 pyrenoids (Text-Figs. 1, 2) which almost lie



TEXT-FIGS. 1-7. *Roya kumaoense* sp. nov. Figs. 1, 2. Mature vegetative cells. Figs. 3-5. Stages in terminal conjugation. Note horn-shaped mature zygospore in Fig. 3. Fig. 6. Stage in lateral conjugation. Fig. 7. An abnormal case of terminal conjugation. Note one of the conjugating cells has not yet separated from its sister cell. All,  $\times 445$ .

equidistant from one another. The chloroplast does not show any sign of longitudinal ribbing, but has a lateral embayment near the middle where the nucleus is lodged (Text-Figs. 1, 2). The cells frequently contain droplets of oily nature (Text-Figs. 1, 2, 7).

**B. Reproduction.**—Sexual reproduction takes place predominantly by terminal conjugation (Text-Figs. 3-5, 7; Plate I, Figs. 1-3, 5-7), but sub-terminal (Plate I, Fig. 4 a) and lateral (Text-Fig. 6) conjugations are also occasionally met with. The details connected with the sexual conjugation are rather interesting and so are discussed at some length below.

Conjugation usually occurs between fully mature cells (Text-Figs. 3, 4), but occurs quite often between recently formed cells also (Text-Figs. 5, 7; Plate I, Fig. 1-3 b, 5-7). The mating cells almost may be of

the same (Text-Figs. 3-5; Plate I, Figs. 1, 2, 3 *b*, 5-7) or of different lengths (Text-Fig. 6; Plate I, Fig. 4 *a*). In terminal conjugation, the mating cells approach each other (Plate I, Figs. 1, 5) and meet terminally. They may either remain straight (Text-Figs. 4, 5, 7; Plate I, Figs. 5-7) or more commonly become slightly arched (Text-Figs. 3; Plate I, Figs. 1, 3). They do not develop any papillate outgrowth. The wall at the point of contact gelatinizes, probably due to some enzymatic action, and a wide pore develops. In sub-terminal (Plate I, Fig. 4 *a*) and lateral (Text-Fig. 6) conjugations, however, the mating cells come to lie parallel to each other and each one develops a papillate outgrowth similar to that found in conjugating cells of Zygnemataceae. The papillate outgrowth gelatinizes in the manner described above and a clear-cut circular pore develops. Regardless of the mode of conjugation the naked gametes escape through the pore and fuse to form a zygote midway between the old parent cell walls (Text-Figs. 3-7; Plate I, Figs. 2, 3, 4 *a*, 6, 7). In some abnormal cases it has been seen that the terminal conjugation and zygospore formation occur even before one of the conjugating cells has separated from its sister cell (Text-Fig. 7).

Zygospores are usually globose (Text-Figs. 4-7; Plate I, Fig. 2, 3 *b*, 4 *a*, 6, 7), but in some cases they are horned (Text-Figs. 3). The horn-like projections probably develop due to incomplete amalgamation of the two fusing gametes (*cf.* Plate I, Fig. 2). The figure on the right-hand side shows an early stage in gametic fusion. The projection on either side may be compared with the horns of a mature zygospore (Text-Fig. 3). Zygospore is thick-walled and smooth and the wall consists of three layers, a thin exospore, a thick blue mesospore and a thin endospore. Mature zygospores measure  $23.4-42.5\mu$  across.

#### DISCUSSION

The present alga differs from all the previously described species of *Roya*. In *R. obtusa* the cells are  $9.15\mu$  broad and  $75-148\mu$  long and its chloroplast has 4-8 pyrenoids. In *R. cambrica* the cells are  $6.2-6.7\mu$  broad and  $173-77\mu$  long and its chloroplast has 12-14 pyrenoids. In *R. pseudoclosterium* the cells are  $2.6-3.5\mu$  broad and  $96-192\mu$  long and its chloroplast has 4-6 pyrenoids. In *R. anglica* the cells are  $7.5-9\mu$  broad and  $35-112\mu$  long and its chloroplast has 4-6 pyrenoids. In the present alga the cells are  $15.6-19.5\mu$  broad and  $97.8-128.8\mu$  long and its chloroplast contains 4-14 pyrenoids. It differs from all the four previously described species in size of cells and number of pyrenoids. It comes closer to *R. obtusa* and *R. anglica* in possessing globose and smooth-walled zygospores. It, however, differs from these species in its method of terminal conjugation. The present alga, therefore, appears to be a new species and may be called *Roya kumaoense* sp. nov.

*Roya kumaoense* spec. nov.

Cellulae vegetativae cylindricae apicibus rotundatis, ut plurimum-rectae, raro arcuatae; cellulae generatim uniformiter crassae, raro



fastigatae e polo ad polum; cellulae  $15.6-19.5\mu$  latae,  $97.8-128.8\mu$  longae; chloroplasta axialia pyrenoideis 4-14 ornata in serie media; conjugatio ut plurimum terminalis, raro subterminalis vel lateralis; zygosporae parietes crassi, globosi, raro cornuti,  $23.4-42.5\mu$  diam., zygosporae parietes crassi, leves et ter seriati, mesosporio crasso, levi et caeruleo.

*Habitat.*—In saxis stillantibus prope Ramsay Hospital, ad Naini Tal in India, mense Augusto anni 1959.

*Roya kumaoense* sp. nov. (Text-Figs. 1-7; Plate I, Figs 1-7).

Vegetative cells cylindrical with rounded poles, usually straight rarely arcuate; cells generally of uniform thickness throughout, really tapering from pole to pole; cells are  $15.6-19.5\mu$  broad and  $97.8-128.8\mu$  long; chloroplast axile with 4-14 pyrenoids in a median series; conjugation mostly terminal, rarely sub-terminal or lateral; zygosporae usually globose, rarely horned and are  $23.4-42.5\mu$  across; zygosporae wall thick, smooth and three-layered; mesosporae thick, smooth and blue in colour.

*Habitat.*—Growing on a dripping rock near Ramsay Hospital, Naini Tal, India (August, 1959).

#### KEY TO THE SPECIES OF *Roya*

- |   |    |    |                            |
|---|----|----|----------------------------|
| 1. Zygosporae present   | .. | .. | 2                          |
| 1. Zygosporae absent  | .. | .. | 3                          |
| 2. Lateral conjugation only   | .. | .. | 4                          |
| 2. Terminal, sub-terminal and lateral conjugation                       | .. | .. | <i>R. kumaoense</i>        |
| 3. Cells $6.2-6.7 \times 173-177\mu$ ; chloroplast with 12-14 pyrenoids | .. | .. | <i>R. cambrica</i>         |
| 3. Cells $2.6-3.5 \times 96-192\mu$ ; chloroplast with 4-6 pyrenoids    | .. | .. | <i>R. pseudoclosterium</i> |
| 4. Cells $9-15 \times 75-148\mu$ ; chloroplast with 4-8 pyrenoids       | .. | .. | <i>R. obtusa</i>           |
| 4. Cells $7.5-9 \times 35-112\mu$ ; chloroplast with 4-6 pyrenoids      | .. | .. | <i>R. anglica</i>          |

#### SUMMARY

The genus *Roya* (West et West) Hodgetts, a rare Saccoderm desmid, has so far been reported from Europe, Siberia and U.S.A. Another species, viz., *Roya kumaoense* sp. nov., has been recorded from Naini Tal, India.

The structure and the reproduction of this species is described in detail. It differs from all other previously described species of *Roya* in having terminal conjugation and broader cells,

A key to the species of *Roya* is given.

#### ACKNOWLEDGMENTS

In conclusion the author expresses his gratitude to Prof. M. O. P. Iyengar for his kindness in examining the sample of *Roya kumaoense* sp. nov. and communicating his valuable suggestions.

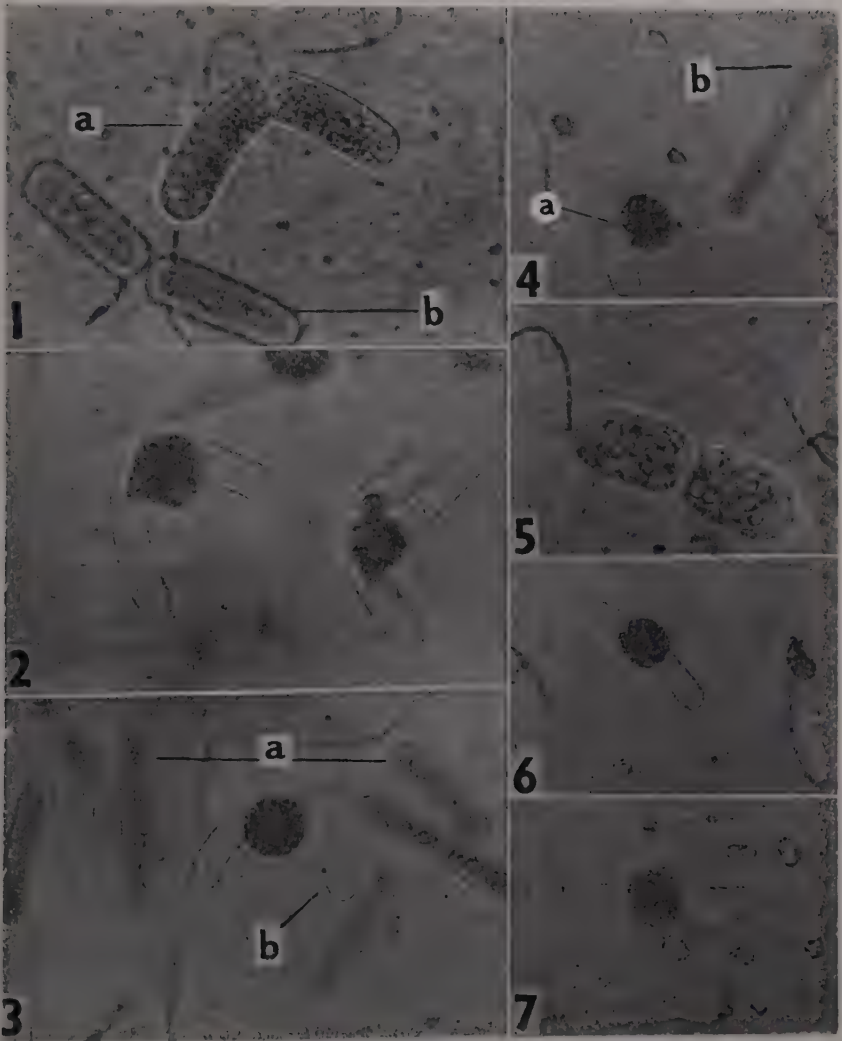
#### REFERENCES

- HODGETTS, W. J. 1920. *Roya anglica* G. S. West, a new desmid, with an amended description of the genus *Roya*. *J. Bot., Lond.* **58**: 65-69.
- KOSSINSKAJA, C. C. 1952. *Flora plantarum cryptogamarum URSS*, Vol. II, *Conjugatae* (1), *Mesotaeniales et Gonatozygales*, 163 pp. Acad. Sci. URSS, Inst. Bot. Moscow.
- WEST, W. AND WEST, G. S. 1896. On some new and interesting fresh-water algae, *J. Roy. micr. Soc.* 1896, **16**: 146-65.
- , 1904. *A Monograph of the British Desmidiaceae*. **1**: 224. London.
- , 1923. *Ibid.* **5**: 191. London.

#### EXPLANATION OF PLATE I

FIGS. 1-7. *Roya kumaoense* sp. nov.

- FIG. 1. Early stage in terminal conjugation. Note in Fig. 1 *a* conjugating cells are arched, while in Fig. 1 *b* they are almost straight.
- FIG. 2. Stages in gametic fusion.
- FIG. 3. Mature vegetative cells and a stage in terminal conjugation with mature globose zygospor.
- FIG. 4. *a*. Stage in sub-terminal conjugation. *b*. A mature vegetative cell showing gradual tapering from one pole to the other.
- FIG. 5. An early stage in terminal conjugation between two recently formed cells.
- FIGS. 6-7. Stages in terminal conjugation where the conjugating cells lie in a straight line.



Kamala P. Singh

FIGS. 1-7





# STUDIES ON THE INTERSPECIFIC HYBRID OF *PENNISETUM TYPHOIDES* × *P. PURPUREUM*

## VI. The Cross Derivatives of the Allotetraploid

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(Received for publication on August 21, 1959)

THE synthesis of 10 allotetraploids in *Pennisetum* was reported in an earlier paper and of these, nine were reasoned out to possess each the genomic constitution AAA'B ( $2n-28$ ), where A was the basic genome of Cumbu, *Pennisetum typhoides* Stapf. and Hubb., and A'B the haploid complement of the Napier grass, *P. purpureum* Schumach. Consequently, the meiosis of these nine allotetraploids revealed the expected association of seven trivalents and seven univalents or its modifications (Krishnaswamy and Raman, 1956). The observations on the plants derived from a single allotetraploid by selfing and by further pollinations are presented in this paper.

### MATERIAL AND METHODS

Of the nine allotetraploids obtained, one plant with the lowest (47.2%) pollen sterility was selected for further hybridization. The protogyny present in the allotetraploid was utilized for crossing with pollen from diploid and autotetraploid *P. typhoides* and emasculation was not necessary. The allotetraploid was also selfed and a few seeds were obtained to raise a progeny.

Meiotic associations were observed from temporary acetocarmine squashes of the anthers after fixing the panicles in acetic alcohol (1 : 3).

### OBSERVATIONS

1. *Allotetraploid selfed*.—Three plants were obtained by selfing and two of these were hexaploids ( $2n-42$ ). These two plants revealed maximum meiotic associations of 3 (iv) + 4 (iii) + 7 (ii) + 4 (i) and 4 (iv) + 3 (iii) + 7 (ii) + 3 (i) respectively. These hexaploids were different from the hexaploids derived as colchicine induced amphidiploids or as  $F_2$  of the interspecific hybrid (Krishnaswamy and Raman, 1954).

The third plant obtained by selfing was a tetraploid ( $2n-28$ ) and closely resembled its mother both in external morphology and in meiotic associations giving a maximum association of 7 (iii) + 7 (i).

2. *Allotetraploid* × *autotetraploid P. typhoides*.—Three hybrids were derived from this cross. Two of them were tetraploids ( $2n-28$ ) but were different from the mother, in having more compact panicles and other characters associated with the cultivated *P. typhoides*. Maximum meiotic associations were 4 (iv) + 3 (iii) + 3 (i) and 3 (iv) + 4 (iii) + 4 (i) respectively.

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TABLE I

PARENTS			Hybrid $2n$	MEIOTIC ASSOCIATIONS										No. of cells examined			
Female	$2n$	Male		$2n$	MAXIMUM					MINIMUM							
					(v)	(iv)	(iii)	(ii)	(i)	(v)	(iv)	(iii)	(ii)		(i)		
Allotetraploid (Selfed)	28	..	42	..	3	4	7	4	..	17	8	..	0.6	3.3	12	5.8	16
			42	..	4	3	7	3	..	18	6	..	0.57	3.7	11.1	6.3	14
			28	..	..	7	..	7	1	7	11	..	..	2.5	6.2	8.1	25
Allotetraploid	28	Autotetraploid <i>Pennisetum typhoides</i>	28	..	4	3	..	3	..	8	12	..	0.8	1.4	6.5	7.6	22
			28	..	3	4	..	4	..	10	8	..	1.1	1.6	6	6.8	17
			42	3	4	..	..	11	..	14	14	0.4	3.7	1.2	4.6	12.4	50
Allotetraploid	28	<i>P. typhoides</i>	14	..	7	..	..	7	1	12	8	..	3.0	1.5	5.1	8.2	50



The third hybrid of this cross was a hexaploid ( $2n=42$ ). Theoretically this should form 7 (v) + 7 (i) during meiosis, though the maximum association observed was 3 (v) + 4 (iv) + 11 (i), which is only a modification of the expected association.

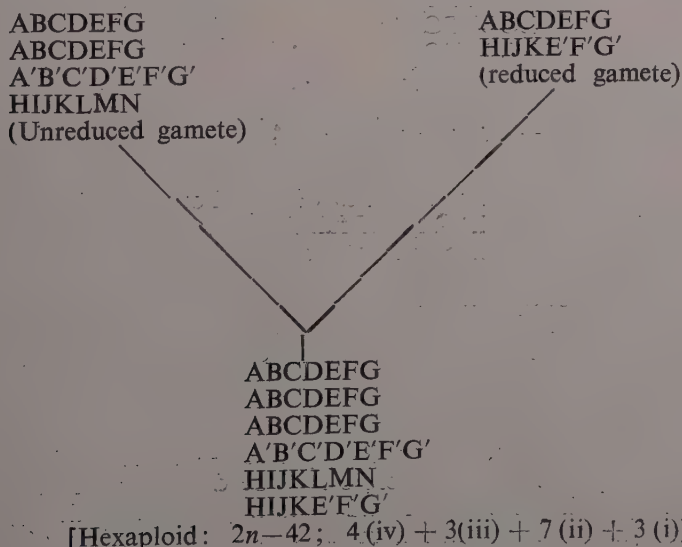
3. *Allotetraploid*  $\times$  *diploid* *P. typhoides*.—Out of several pollinations, one plant with  $2n=35$  chromosomes was obtained. This pentaploid showed a maximum association of 7 (iv) + 7 (i) as expected.

The meiotic associations of the above derivatives of the allotetraploid are consolidated in Table I.

#### DISCUSSION

1. *Allotetraploid selfed*.—The 42-chromosomed plants in the progeny may be due to the fusion of an unreduced gamete ( $2n=28$ ) with another having the reduced number ( $n=14$ ). However, the meiosis in the allotetraploid is not normal as a result of high frequency of trivalent associations. It has already been mentioned that the allotetraploid possesses the genomes AAA'B and forms a maximum association of 7 (iii) + 7 (i) at meiosis. Due to random distribution of the univalents and disjunction of the trivalents, the distribution at I-anaphase is frequently 14-14 but sometimes unequal. It will not be possible to speculate how many complete genomes are included in each of the I-telophasic nuclei, besides other chromosomes the nature of which cannot be specified. In other words, the exact gametic constitutions of the allotetraploid cannot be stated though the genomes are known.

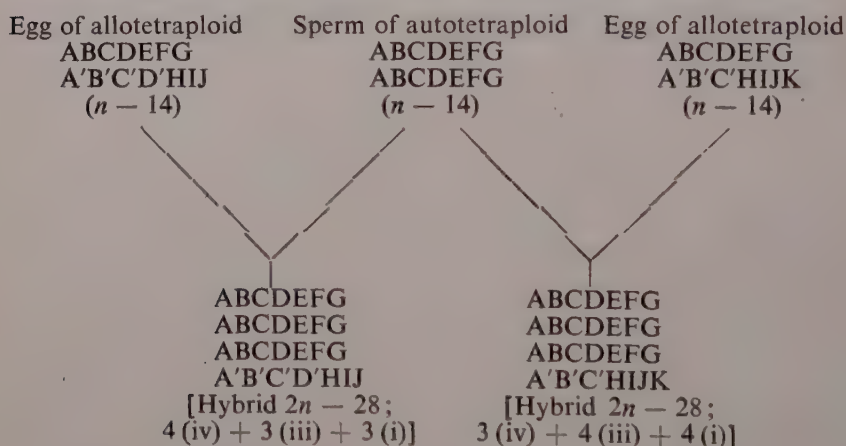
However, since the hexaploid ( $2n=42$ ) derived by selfing the allotetraploid, forms a maximum association of 4 (iv) + 3 (iii) + 7 (ii) + 3 (i), the constitution of the hexaploid can be represented as follows (denoting the A genome by the chromosomes ABCDEFG, the A' genome by A'B'C'D'E'F'G' and the B genome by HIJKLMN):—



The other hexaploid probably has one more D' instead of one K, since it forms a maximum of only three quadrivalents. It is now apparent that the reduced gamete of the allotetraploid contributes one full genome and seven other chromosomes at random from A, A' and B genomes.

The third selfed derivative is 28-chromosomed and forms a maximum association of  $7(\text{iii}) + 7(\text{i})$ . Evidently, this plant has the same chromosome constitution as the mother and this is further supported by the similar appearance between this tetraploid and its parent. While two reduced gametes may unite to develop into an exact genetic constitution as the mother plant, the chances for such a combination are perhaps very remote. However, the probability of parthenogenetic development of an unreduced female gamete cannot be entirely overlooked. A parallel example is the development of diploids from autotetraploid *P. typhoides* when the latter was selfed (Raman, unpublished).

2. *Allotetraploid*  $\times$  *autotetraploid P. typhoides*.—The constitution of the two 28-chromosomed hybrids can be represented as follows:—



Here again the reduced gamete of the allotetraploid mother has contributed gametes each with one full A genome (chromosomes A–G) and also seven more chromosomes at random from A, A' and B genomes.

The third hybrid of this cross is a hexaploid ( $2n - 42$ ) and is probably the result of fusion of an unreduced egg with the reduced diploid ( $n - 14$ ) male gamete. Consequently the genomic constitution of the hexaploid is AAAA'A'B and it forms a maximum association of  $3(\text{v}) + 4(\text{iv}) + 11(\text{i})$ .

3. *Allotetraploid*  $\times$  *diploid P. typhoides*.—The single 35-chromosomed plant produced in this cross may be due to an unreduced egg fertilized by a haploid sperm and evidently possesses the genomes AAAA'A'B and forms a maximum association of  $7(\text{iv}) + 7(\text{i})$ .

The reciprocal of the above cross has also resulted in a pentaploid and a triploid plant. The chromosome constitution of the latter was reasoned out to be AAA'BBB'CCC'DDDD'EEEE'FFGG (Raman and Krishnaswami, 1959); here again the reduced gamete of the allotetraploid has contributed one full A genome in addition to seven chromosomes at random from A and A' genomes but not B.

In all the above selfed and cross progenies of the allotetraploid, the incidence of aneuploids has not been met with, though evidences for the production of aneuploid gametes in the allotetraploid mother are known (Krishnaswamy and Raman, 1956). It is therefore evident that gametes with aneuploid numbers probably are not viable. But the 14-chromosomed gametes do function irrespective of their constitution. It is also evident that the allotetraploid produces a number of unreduced gametes. It may be probable that unreduced gametes are functional more on the female side than on the male, since the meiosis in the microsporocytes has not revealed any evidence for formation of unreduced gametes (Krishnaswamy and Raman, 1956).

The hexaploid derived in the cross between allotetraploid and autotetraploid possesses the genomic constitution AAAAA'B but the characters of the wild parent *P. purpureum* are still expressed indicating the high degree of dominance of the B genome over as many as five A genomes.

#### SUMMARY

A selected allotetraploid *Pennisetum* ( $2n=28$ ) produced two 42- and one 28-chromosomed plants on selfing, two 28- and one 42-chromosomed plants on pollination with autotetraploid *P. typhoides* and one 35-chromosomed plant on pollination with diploid *P. typhoides*. The genomic constitutions of these seven derivatives of the allotetraploid have been analysed.

#### REFERENCES

- KRISHNASWAMY, N. AND RAMAN, V. S. 1954. Studies on the interspecific hybrid of *Pennisetum typhoides*  $\times$  *P. purpureum*. III. The cytogenetics of the colchicine-induced amphidiploid. *Genetica* 27: 253-72.
- . 1956. Studies on the interspecific hybrid of *Pennisetum typhoides*  $\times$  *P. purpureum*. IV. The cytogenetics of the allotetraploids. *Ibid.* 28: 345-60.
- RAMAN, V. S. AND KRISHNASWAMI, D. 1959. Studies on the interspecific hybrid of *Pennisetum typhoides*  $\times$  *P. purpureum*. V. The cytology of an allotriploid plant. *J. Indian bot. Soc.* 39: 382-85.



# CALCICOLE AND CALCIFUGE PROBLEM IN *EUPHORBIA THYMIFOLIA* LINN.

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CALCICOLOUS plants or 'calcicoles' are commonly defined as plants growing in neutral or alkaline soils rich in calcium. Calcifugous plants or 'calcifuges' are defined as plants growing in calcium-poor, acidic soils. Daubenmire (1947) states that there is a gradation of tolerance and/or requirements of calcium among plant species. Hence, it is but natural that the flora developed in calcareous soils and non-calcareous soils are distinctive of each habitat (Pesola, 1928; Webb, 1947; Coombe and White, 1951; Whittaker, 1954; Walker, 1954; Kruckeberg, 1954).

The restriction of calcicoles to calcareous soils and calcifuges to non-calcareous soils may not be explainable on the basis of a single factor. Christ as early as 1897 recognised calcicole and calcifuge species in the genus *Achilla* and attributed their restricted occurrence to competitive advantage of these species in their respective habitats. Tansley (1917) has recognised a calcicolous species in *Galium sylvestra* and a calcifugous species in *G. saxatile* and accounts the phenomenon as due to germination, competition and growth performance of the two species in calcareous and non-calcareous soils. Rayner (1921) working upon the calcifuge habitat in *Calluna vulgaris* attributes the absence of this species in calcareous soils as due to delayed and poor germination of seeds, arrested growth and parasitic effect of the originally symbiotic fungus.

Workers in the field hold different views in explaining the behaviour of the calcicoles and calcifuges. Pearsall and Wray (1927) consider the 'basic ratio'  $(K + Na)/Ca$  as the main factor responsible for the distribution of plant species. Rayner (1921) suggests three possibilities for the absence of calcifuges from calcareous soils—(i) the presence of a toxic substance in calcareous soils, (ii) low H-ion concentration of the soil solution, and (iii) the difference in the effective concentration of the soil solution. Salisbury (1920) divides calcicoles into (i) Pseudo-calcicoles—plants which frequent calcareous soils on account of the physical features of such soils, and (ii) oxyphobics—plants that are intolerant of high acidities in soil.

In *Euphorbia thymifolia* Linn., two ecotypes have been recognised: (i) the red form and (ii) the green form. The former grows in calcareous as well as non-calcareous soils while the latter can thrive only

in calcium-poor soils (Ramakrishnan, 1958). These two, by interbreeding, give rise to three intermediate forms.

#### BREEDING BEHAVIOUR OF *Euphorbia thymifolia* LINN.

Before we enter into a discussion of the ecological distribution pattern in this plant, it will be worth while to note the breeding behaviour of the two ecotypes—the red form and the green form.

Prior to any breeding programme, the construction of floral parts and the time of dehiscence of anthers, etc., have to be noted. In *E. thymifolia*, the male flowers which are represented by single stamens are raised to a higher level by the elongation of the stalk at the time the anthers are mature. The dehiscence occurs by a split of the anther lobes. The time of dehiscence of anthers is found to be between 8 A.M. and 12 NOON with 9 A.M. to 10 A.M. as the peak hour.

Due to the minuteness of the plants as such, and the floral parts in particular, special methods had to be devised for selfing the plants. This has been achieved by enclosing whole of the potted plant with transparent cellophane paper and making provision for aeration through wide glass tubes plugged with cotton.

The red form has a red colour developed throughout the plant body while the green form is completely green with no reddish tinge on it. Two plants belonging to the two colour groups were selfed separately and 50 plants were raised up in each case from the seeds thus obtained. The progenies in each case were found to be same as the parent plant, thus confirming the homozygous nature of the parents.











In the green form all the inflorescences were removed carefully except a few young ones and from these too, the anthers were removed with least injury to the central gynoeceum. The dehiscing anthers from the red form were removed by means of fine forceps and touched upon the stigmatic head of the green parent. This process was repeated daily with the same two plants, till fruit formation. Two plants raised up from the seeds thus obtained were of an intermediate type—greenish throughout the plant body except on the undersurface of the leaves, especially along the veins where there is development of red anthocyanin pigments.

The  $F_2$  generation of plants were found to follow a ratio of 15:1 in which 15 include four grades of redness and the 1 being complete green. To be more precise, the  $F_2$  ratio is recognisable in 1:4:6:4:1, starting with pure red form and ending in the green form with three intermediates. An analysis of the progeny is given in Table I.

By referring to  $\chi^2$  table for a degree of freedom  $n = 4$  and  $P = 0.05$ , the value is 9.488 which is higher than the observed value (0.81 and 0.564) and hence the assumption that the observed ratio is 1:4:6:4:1 is correct and the deviation of the observed from the expected values is only due to chance.

TABLE I

*Inheritance of anthocyanin pigmentation in Euphorbia thymifolia*  
( $F_2$  generation)

Total No. of plants raised	F <sub>1</sub> plant No. 1					F <sub>1</sub> plant No. 2				
	176					104				
	Different grades of Red					Different grades of Red				
										
Observed Ratio	9	46	64	47	10	7	27	37	25	8
Expected Ratio	11	44	66	44	11	6.5	26.0	39.0	26.0	6.5
Deviation	2	2	2	3	1	0.5	1.0	2.0	1.0	1.5
	$\chi^2 = 0.81$					$\chi^2 = 0.564$				

The whole scheme following Nilsson-Ehle (1908) may be represented as follows:

Parent		$R_1R_1R_2R_2'$	$\times$	$r_1r_1r_2r_2$	
F <sub>1</sub> generation		$R_1r_1R_2r_2$			
		$R_1R_2$	$R_1r_2$	$r_1R_2$	$r_1r_2$
F <sub>2</sub> generation	$R_1R_2$	$R_1R_1R_2R_2$	$R_1R_1R_2r_2$	$R_1r_1R_2R_2$	$R_1r_1R_2r_2$
	$R_1r_2$	$R_1R_1R_2r_2$	$R_1R_1r_2r_2$	$R_1r_1R_2r_2$	$R_1r_1r_2r_2$
	$r_1R_2$	$R_1r_1R_2R_2$	$R_1r_1R_2r_2$	$r_1r_1R_2R_2$	$r_1r_1R_2r_2$
	$r_1r_2$	$R_1r_1R_2r_2$	$R_1r_1r_2r_2$	$r_1r_1R_2r_2$	$r_1r_1r_2r_2$

Thus, five forms have been distinguished based upon the degree of development of the red pigment and the actual colour of the plant body, by referring to a standard colour chart, is given for each of the genetical variants.



1. *Red form*  $\begin{pmatrix} RR \\ RR \end{pmatrix}$ .—This is pure breeding. The stem, petiole of leaves and floral parts are red in colour. The leaves also have a reddish tinge on them, prominently so along the veins on the undersurface of the leaves.

Stem, petiole of leaves, veins on the undersurface of the leaves, floral parts—Peony (Maerz and Paul, 1930; Pl. 7 H, 6).

Leaf, upper side—Aspen green (Maerz and Paul, 1930; Pl. 31 E, 6).

Leaf, lower side—Artemesia green (Maerz and Paul, 1930; Pl. 30 F, 2).

2.  $\begin{pmatrix} Rr \\ RR \end{pmatrix}$ .—The red colour is less deep and less prominent than in the above form.

Stem, petiole of leaves, floral parts—Fawn or Sandalwood (Maerz and Paul, 1930; Pl. 14 A, 7).

Veins on the undersurface of leaves—Sultana (Maerz and Paul, 1930; Pl. 7 C, 5).

Leaf, upper side—Almond green (Maerz and Paul, 1930; Pl. 30 E, 6).

Leaf, lower side—lighter than upper side (Maerz and Paul, 1930; Pl. 30 A, 6).

3.  $\begin{pmatrix} Rr \\ rR \end{pmatrix}$ .—This is the hybrid obtained in a cross between the red and green forms. The plant is completely green, the red colour being confined only to the undersurface of the leaves more prominently along the veins.

Stem, petiole of leaves, floral parts—Calla green (Maerz and Paul, 1930; Pl. 22 L, 4).

Leaf, upper and lower sides—Russian green (Maerz and Paul, 1930; Pl. 30 D, 7).

Veins on the undersurface of leaves—Tapestry red (Maerz and Paul, 1930; Pl. 7 J, 5).

4.  $\begin{pmatrix} Rr \\ rr \end{pmatrix}$ .—The reddish tinge is very light being confined only to the midrib on the undersurface of leaves.

Stem, petiole of leaves and floral parts—Courge green (Maerz and Paul, 1930; Pl. 21 L, 3).

Leaf, upper side—Silver pine (Maerz and Paul, 1930; Pl. 30 E, 5).

Leaf, lower side—Lighter than upper side (Maerz and Paul, 1930; Pl. 30 A, 4).

Midrib on the undersurface of leaves—Sultana (Maerz and Paul, 1930; Pl. 7 C, 5).

5. Green form  $\begin{pmatrix} r & r \\ r & r \end{pmatrix}$ .—This is pure breeding form and the plant body is completely green.

Stem, petiole of leaves, floral parts—Cource green (Maerz and Paul, 1930; Pl. 21 L, 3).

Leaf, upper side—Silver pine (Maerz and Paul, 1930; Pl. 30 E, 5).

Leaf, lower side—Lighter than upper side (Maerz and Paul, 1930; Pl. 30 A, 4).

The pattern of inheritance of pigmentation detailed above is confirmed by raising  $F_3$  populations of the various forms.

(1) Red form ( $R_1R_1R_2R_2$ ).—52  $F_3$  plants raised up following the usual procedure for selfing were found to be of the same type as the parent plant showing the pure nature of the parent.

(2)  $R_1R_1R_2r_2$  or  $R_1r_1R_2R_2$ .—82  $F_3$  plants raised up segregated in a ratio of  $\begin{pmatrix} RR \\ RR \end{pmatrix} : \begin{pmatrix} Rr \\ RR \end{pmatrix} : \begin{pmatrix} Rr \\ rR \end{pmatrix} = 1:2:1$  and the results are given in Table II.

TABLE II

$F_3$  generation:  $R_1r_1R_2R_2$  or  $R_1R_1R_2r_2$

Total number of plants raised = 82

Different grades of Red					
			<div>RR RR</div>	<div>Rr RR</div>	<div>Rr rR</div>
Observed ratio	..	..	19	44	19
Expected ratio	..	..	20.5	41.0	20.5
Deviation ...	..	..	-1.5	3.0	1.5
$\chi^2 = 0.439$					

For  $n = 2$  and  $P = 0.05$ , the value from  $\chi^2$  table is 5.991 which is much greater than the value calculated. Hence, the segregation






$\begin{pmatrix} RR \\ RR \end{pmatrix} : \begin{pmatrix} Rr \\ RR \end{pmatrix} : \begin{pmatrix} Rr \\ rR \end{pmatrix} = 1:2:1$  is correct,

(3)  $R_1r_1R_2r_2$ .—This is genotypically the same as the  $F_1$  progeny and  $F_3$  plants segregate in a ratio of 1:4:6:4:1 (Table III).

TABLE III

$F_3$  generation :  $R_1r_1R_2r_2$

Total number of plants raised = 74

		Different grades of Red				Green
						
Observed ratio	..	4	19	28	19	4
Expected ratio	..	4.625	18.5	27.75	18.5	4.625
Deviation	..	0.625	0.5	0.25	0.5	0.625
		= 0.208				

The observed value 0.208 is much less than the value 9.488 given in  $\chi^2$  table for  $n = 4$  and  $P = 0.05$ . Hence, the deviation from the expected ratio is only due to chance errors.




(4)  $R_1R_1r_2r_2$  or  $r_1r_1R_2R_2$ .—This form is phenotypically same as  $R_1r_1R_2r_2$ , but genotypically different in that there is no segregation in the ratio 1:4:6:4:1. 58  $F_3$  plants raised were found to give rise to the same type of progeny.

(5)  $R_1r_1r_2r_2$  or  $r_1r_1R_2r_2$ .—122  $F_3$  plants were raised up and the results are set in Table IV.

TABLE IV

$F_3$  generation:  $R_1r_1r_2r_2$  or  $r_1r_1R_2r_2$

Total number of plants raised = 122

				
Observed ratio	..	27	64	31
Expected ratio	..	30.5	61	30.5
Deviation	..	3.5	3	0.5
		$\chi^2 = 0.566$		



From  $\chi^2$  table, for  $n = 2$  and  $P = 0.05$ , the value is 5.991 which is much higher than the calculated value 0.566. Hence, the segregation

$$\begin{pmatrix} Rr \\ rR \end{pmatrix} : \begin{pmatrix} Rr \\ rR \end{pmatrix} : \begin{pmatrix} rr \\ rr \end{pmatrix} = 1 : 2 : 1 \text{ is correct.}$$

(6) *Green form* ( $r_1r_1r_2r_2$ ).—58  $F_3$  plants of this form were raised up and they were found to breed pure which is according to expectation.

Thus, a study of  $F_3$  generation confirms the  $F_2$  ratio obtained. This type of inheritance comes under 'multiple factor hypothesis' or 'duplicate factor hypothesis' and was first discovered by Nilsson-Ehle (1933) in the case of the pigmentation in the kernels of the two strains of wheat. This concept of Nilsson-Ehle (1908) was quickly extended by East (1910) and confirmed later by further experimental work. Thus, for example, the awned *versus* non-awned condition in rice is also governed by a duplicate factor (as quoted by Chandrasekharan and Parthasarathy, 1953).

#### DISTRIBUTION OF ANTHOCYANIN PIGMENTS

The anthocyanin pigments are confined to the epidermal cells only. Sometimes, a few of the sub-epidermal cells also may have this pigment.

#### CALCICOLE AND CALCIFUGE HABIT

With a knowledge of the breeding behaviour of the various forms of *E. thymifolia* just discussed, it would be interesting to study their ecological distribution.

Of the five forms,  $\begin{pmatrix} RR \\ RR \end{pmatrix}$  and  $\begin{pmatrix} Rr \\ RR \end{pmatrix}$  are found to grow in calcium-rich soils as well as in soils poorer in exchangeable calcium; the other three forms  $\begin{pmatrix} Rr \\ rR \end{pmatrix}$ ,  $\begin{pmatrix} Rr \\ rr \end{pmatrix}$  and  $\begin{pmatrix} rr \\ rr \end{pmatrix}$  are restricted to calcium-poor soils only.

Hence,  $\begin{pmatrix} RR \\ RR \end{pmatrix}$  and  $\begin{pmatrix} Rr \\ RR \end{pmatrix}$  may be termed as facultative calcicoles, while  $\begin{pmatrix} Rr \\ rR \end{pmatrix}$ ,  $\begin{pmatrix} Rr \\ rr \end{pmatrix}$  and  $\begin{pmatrix} rr \\ rr \end{pmatrix}$  may be termed as obligate calcifuges. The reason for using these two terms will be appreciated after the ecological behaviour of the various forms in relation to soil calcium is discussed in detail.

The soil analysis data regarding pH, exchangeable calcium content and carbonate content for the above two groups are set in Table V.

From Table V, it is seen that the exchangeable calcium is the most significant factor that governs the distribution of facultative calcicoles and obligate calcifuges.

TABLE V

*Soil analysis data for Euphorbia thymifolia*

Exchangeable calcium (mgm. eq. %)	Carbonate content (%)	pH	Remarks
18.00	0.125	6.5	Only facultative calcicole grow
18.50	0.236	8.0	"
20.00	0.614	7.9	"
30.10	3.625	7.9	"
35.85	1.690	8.3	"
49.50	5.044	7.5	"
52.00	3.016	8.5	"
56.00	2.896	8.4	"
84.00	5.250	7.9	"
4.50	0.118	5.6	All the 5 forms grow together
4.75	0.018	7.4	"
5.30	0.138	7.5	"
7.00	0.130	7.4	"
8.40	0.755	7.7	"
11.20	0.920	7.8	"
11.50	1.010	7.5	"

To examine the ecological relationships between the red form and the green form and to analyse the factors responsible for their distribution, detailed culture experiments were undertaken. The following types of soils were prepared in two sets of culture pots:

1. Equal amounts of garden soil and sand.
2. Soil from the region, where all the five forms grow together (calcium-poor soil).
3. Soil from a locality where only the facultative calcicoles grow.
4. Soil with about 30 mgm. eq. % of exchangeable calcium by addition of lime.
5. Soil with about 38 mgm. eq. % of exchangeable calcium.
6. Soil with about 48 mgm. eq. % of exchangeable calcium.
7. Soil with about 50 mgm. eq. % of exchangeable calcium.

The detailed soil analysis data are set in Table VI.

TABLE VI  
*Analysis of soils in culture pots*

Observations	Pot numbers						
	1	2	3	4	5	6	7
Red form { pH .. ..	..	7.6	8.3	8.3	8.3	8.4	10.1
Exchangeable calcium (mgm. eq. %)	..	10.4	25.8	30.0	38.0	48.4	50.5
Carbonate content (%) .. ..	..	0.24	0.10	1.38	1.79	2.93	4.40
Green form { pH .. ..	..	7.6	8.3	8.3	8.4	8.4	10.2
Exchangeable calcium (mgm. eq. %)	..	9.8	24.9	32.0	37.2	48.2	53.1
Carbonate content (%) .. ..	..	0.21	1.10	1.38	1.76	2.80	4.50

100 seeds of each of the red form and the green form were put for germination in each of the two sets of pots. It was found that the seeds from the red form always give rise to the same type of plants only, in all the soils, but the seeds from the green form give rise to both red and green plants in calcium-poor soils. However, in calcareous soils only the red plants grew (Table VII). This anomaly in the green form

is now explained as due to the presence of seeds of  $\begin{pmatrix} Rr \\ rR \end{pmatrix}$  and  $\begin{pmatrix} Rr \\ rR \end{pmatrix}$  also along with those of  $\begin{pmatrix} rr \\ rr \end{pmatrix}$ .

TABLE VII  
*Germination of the seeds of Euphorbia thymifolia in soils maintained at different levels of calcium*

Type of plant	% germination in different pots					
	1	2	3	4	5	6
Red form ..	49	40	48	49	10	5
Green form ..	18 red	23 red	24 red	20 red	5 red	2 red
	57 green					



## Pot Numbers:

1. Equal proportion of sand and garden soil.
2. Soil where facultative calcicoles only grow.
3. Soil with about 30 mgm. eq. % of exchangeable calcium
4.   "       "       "       38   "       "       "
5.   "       "       "       48   "       "       "
6.   "       "       "       50   "       "       "

From Table VII, it is also seen that the red form gives fairly good percentage germination in all the culture pots except the last in which case the low percentage appears to be due to the abnormally high pH of the soil.

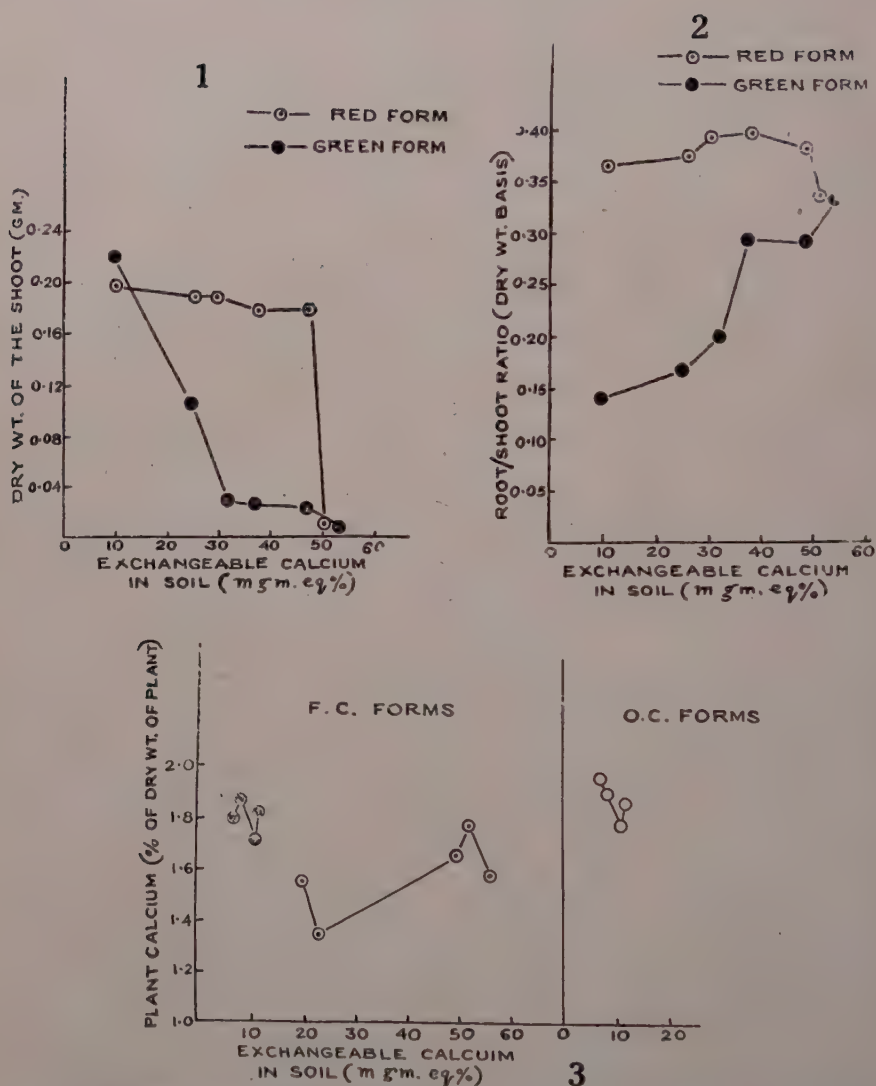
To study the effect of calcium on the performance of the plant in calcareous and non-calcareous soils, two plants were allowed to grow in each of the pots of the two sets. It is found that the performance of the green form expressed on the basis of dry weight of the shoot is much affected in calcareous soils, the best performance being obtained in calcium-poor soils only (Plate II, Fig. B; Text-Fig. 1). In calcareous soils the green form remains stunted and exhibits chlorosis. From a study of the root/shoot ratio for these forms, it is to be noted that the values for this increase considerably in high dosages of lime (Text-Fig. 2). This is due to the profuse development of roots compared to shoots in calcareous soils (Plate II, Fig. B).

Fairly good growth is obtained for the red form in all the pots except the one with about 50 mgm. eq. % of exchangeable calcium, in which case the performance of the plant appears to be affected by the abnormally high pH of the soil as seen from Table VI (Plate II, Fig. A).

From these experiments, it is seen that the germination behaviour and later growth performance in calcareous and non-calcareous soils of the facultative calcicoles and the obligate calcifuges are responsible to a great extent for their distribution pattern in nature.

Captain Marsh (as quoted by Tansley, 1917) has devised a method intended to separate the effects of shoot competition from that of root competition. A wooden box is divided into two equal compartments by means of a sheet of glass and both the compartments are filled with soil. When plants are grown on each of the two sides of this glass sheet, root competition between them is avoided. In other boxes, the glass sheet is put just in the surface layers of the soil and allowed to stand several inches above it, so that it would completely separate the shoots of the plants, but would leave the roots free to penetrate on either side below the glass and compete with each other.

By making use of the above-mentioned method, it has been seen that root competition between facultative calcicoles and obligate calcifuges suppresses the establishment of the latter in calcareous soils. In such soils, the young seedlings of the obligate calcifuges died away



TEXT-FIGS. 1-3. *Euphorbia thymifolia* Fig. 1. Relationship between exchangeable calcium in the soil and dry weight of the shoot, in cultures, in red and green forms. Fig. 2. Relationship between exchangeable calcium in the soil and root/shoot ratio (dry wt. basis), in cultures, in red and green forms. Fig. 3. Correlation between exchangeable calcium in the soil and total plant calcium of facultative calcicoles (F.C. forms) in calcium-poor and calcareous soils and that of obligate calcifuges (O.C. forms) in calcium-poor soils.

wherever root competition was allowed to take place. However, in non-calcareous soils, competition has no ill-effects in the establishment

of any of the five forms, thus making it possible for all the forms to grow side by side.

For a better understanding of the calcicole and calcifuge problem in this species, a detailed analytical study of plant calcium was thought to be of some help. For this, a composite mixture of the fully mature plants of the facultative calcicoles and obligate calcifuges were analysed separately. This procedure was adopted due to the similar ecological behaviour of the forms coming under facultative calcicoles and obligate calcifuges. The results are represented in Text-Fig. 3.

The calcium content of a number of weeds growing in Varanasi has been given by Singh and Singh (1939). Their data are given in Table VIII for the sake of comparison.

TABLE VIII  
*Calcium content of some weeds of Varanasi (as  
given by Singh and Singh, 1939)*

No.	Species	Calcium oxide (% of dry weight of plant)
1	<i>Eclipta alba</i>	1.62
2	<i>Anagallis arvensis</i>	2.12
3	<i>Euphorbia thymifolia</i>	2.31
4	<i>Asphodelus tenuifolius</i>	2.41
5	<i>Scoparia dulcis</i>	2.46
6	<i>Leucas urticaefolia</i>	2.89
7	<i>Solanum xanthocarpum</i>	3.36
8	<i>Digera arvensis</i>	4.45
9	<i>Cassia occidentalis</i>	5.55

Plant calcium for the facultative calcicoles vary from 1.35 to 1.87% of calcium (1.875 to 2.618% of calcium oxide) and for the obligate calcifuges between 1.56% and 1.95% of calcium (2.184 to 2.730% of calcium oxide) on the basis of dry weight of plant, as seen from Text-Fig. 3. A comparison of the results obtained with that given in Table VIII shows that the calcium content of the facultative calcicoles and the obligate calcifuges of *E. thymifolia* is much lower than that of plants like *Cassia occidentalis*, *Digera arvensis* and *Solanum xanthocarpum*.



It is also found that the facultative calcicoles in general have a higher percentage of plant calcium in calcium-poor soils than in calcareous soils. Obligate calcifuges have more or less the same amount of plant calcium as the facultative calcicoles growing along with them.

#### DISCUSSION AND CONCLUSION

The problem of calcicolous and calcifugous habit of plants has been agitating the minds of botanists for a long time and various explanations have been put forward from time to time for this phenomenon.

In *E. thymifolia*, the five forms have been grouped under two heads: (i) Facultative calcicoles, and (ii) Obligate calcifuges. The factors controlling the occurrence of the facultative calcicoles in calcareous as well as non-calcareous soils and the confinement of the obligate calcifuges to calcium-poor soils resolve into three separate phases: (1) germination, (2) seedling establishment and competition, and (3) growth performance.

The importance of germination of seeds with reference to their influence on the formation of associations have been stressed by Hanson (1958). Thus, the sensitiveness of the seeds of the obligate calcifuges seems to be a factor of importance in the restriction of these forms to calcium-poor soils. Tansley (1917) has also made a similar observation with regard to the calcicole and calcifuge species of *Galium*.

Salisbury (1930, 1936) and Salisbury *et al.* (1933) have emphasised the importance of juvenile phase in natural selection. Christ (1897) in *Achilla* and Tansley (1917) in *Galium* have observed that the elimination of calcicolous species of these genera from non-calcareous soils and calcifugous species from calcareous soils is affected by competition between the species of each genus. The present study reveals that the seedlings of the obligate calcifuges are eliminated from calcareous soils due to root competition with the facultative calcicoles. However, in non-calcareous soils, competition is ineffective, thus enabling the survival of all the five forms side by side. Recently Kruckeberg (1954) has reported that a number of plants are restricted to serpentine soils by intolerance of the more rigorous competition in non-serpentine plant communities. Under cultural conditions, even if the obligate calcifuges of *E. thymifolia* are freed from competition, the plants exhibit stunted growth and 'lime chlorosis', an observation also made by Tansley (1917) in *Galium saxatile* and McVean (1953) in *Alnus glutinosa*.

Calcifuge habit has always been associated with an acidic substratum. The present study reveals that the pH of the soil is of lesser consequence in the distribution of calcicoles and calcifuges as there is not much appreciable difference observable in this factor in calcareous and non-calcareous soils at Varanasi. Thus, it appears that the calcifuge habit in the tropics is not necessarily accompanied by acidity of the substratum. Pearsall and Wray (1927) came to the conclusion that pH is not a predominant factor in the distribution of calcifuges and that the basic ratio  $(Na + K)/Ca$  is of greater importance. De Silva (1934)

points out that exchangeable calcium in the soil is a very important factor for calcicoles and calcifuges and that calcium carbonate in soil is of lesser consequence, a conclusion also derived from the present study.

Singh and Singh (1939) have estimated the calcium content of a number of weeds growing in Varanasi. For the so-called calcium weeds like *Cassia occidentalis* and *Digera arvensis*, they obtained values as high as 5.55% and 4.45% of calcium oxide respectively, on the basis of dry weight of the plant. Such high values for plant species does not imply that they are calcicolous in habit. Misra and Siva Rao (1948) therefore rightly point out that the so-called calcium weeds need not be calcicolous. They have obtained a definite correlation between exchangeable calcium in the soil and plant calcium. On the contrary, the values for plant calcium are markedly low in *E. thymifolia*. It is interesting to find that

the calcium content of  $\begin{pmatrix} RR \\ RR \end{pmatrix}$  and  $\begin{pmatrix} Rr \\ RR \end{pmatrix}$  in calcareous soils is lower than that in non-calcareous soils. This fact is of great significance in that it means a poor uptake of calcium by these plants in calcareous soils than in calcium-poor soils. In fact, one may expect a high calcium content in these plants in calcareous soils, by virtue of their occurrence in soils having high exchangeable calcium. The above results, therefore, lead one to the

conclusion that  $\begin{pmatrix} RR \\ RR \end{pmatrix}$  and  $\begin{pmatrix} Rr \\ RR \end{pmatrix}$  are calcicolous not by preference, but just because of their surviving capacity in calcareous soils. In other words, they are facultative calcicoles. The other three forms

$\begin{pmatrix} Rr \\ rR \end{pmatrix}$ ,  $\begin{pmatrix} Rr \\ rr \end{pmatrix}$  and  $\begin{pmatrix} rr \\ rr \end{pmatrix}$  thrive only in calcium-poor soils and hence are termed as obligate calcifuges.

Kruckeberg (1954) has observed in the case of 'bodenvag species' (those occurring on and off serpentine soils) that the serpentine species are more tolerant of low calcium levels in the soil than the non-serpentine strains. He has shown, further, that in most cases the populations on serpentine are ecotypically distinct from those on non-serpentine soils. In *E. thymifolia* too, two ecotypes are recognisable: (i) the red form and (ii) the green form, the former tolerant of high calcium levels in the soils and the latter exclusively confined to calcium-poor soils.

#### SUMMARY

In *Euphorbia thymifolia* Linn., two interbreeding forms were observed in the field—(i) the red form, having a red colour throughout the plant body and (ii) the green form. Upon hybridisation, the  $F_2$  plants segregate in the ratio 15: 1, in which 15 represent different grades of red colour of the plant body and the 1 being pure green form. Thus, altogether five forms have been recognised with an  $F_2$  ratio of

$\begin{pmatrix} RR \\ RR \end{pmatrix} : \begin{pmatrix} Rr \\ RR \end{pmatrix} : \begin{pmatrix} Rr \\ rR \end{pmatrix} : \begin{pmatrix} Rr \\ rr \end{pmatrix} : \begin{pmatrix} rr \\ rr \end{pmatrix} = 1 : 4 : 6 : 4 : 1$ . These are found in nature also. It is found that the first two forms mentioned above can grow in calcium-rich soils and calcium-poor soils while the latter three forms can thrive only in non-calcareous soils.  $\begin{pmatrix} RR \\ RR \end{pmatrix}$  and  $\begin{pmatrix} Rr \\ rR \end{pmatrix}$  have been termed as facultative calcicoles and the other three as obligate calcifuges. The obligate calcifuges are very sensitive to calcium with regard to their germination and seedling growth. Moreover, the absence of calcifuge forms in calcareous soils is accounted for as due to severe root competition between  $\begin{pmatrix} RR \\ RR \end{pmatrix}$  and  $\begin{pmatrix} Rr \\ RR \end{pmatrix}$  versus  $\begin{pmatrix} Rr \\ rR \end{pmatrix}$ ,  $\begin{pmatrix} Rr \\ rr \end{pmatrix}$  and  $\begin{pmatrix} rr \\ rr \end{pmatrix}$ . It has been discussed that the calcifuge habit of plants in the tropics is not necessarily accompanied by acidity of the substratum. Thus, two ecotypes have been established in *E. thymifolia*: (i) the red form and (ii) the green form, the former being tolerant of calcareous as well as non-calcareous soils and the latter thriving only in non-calcareous soils.

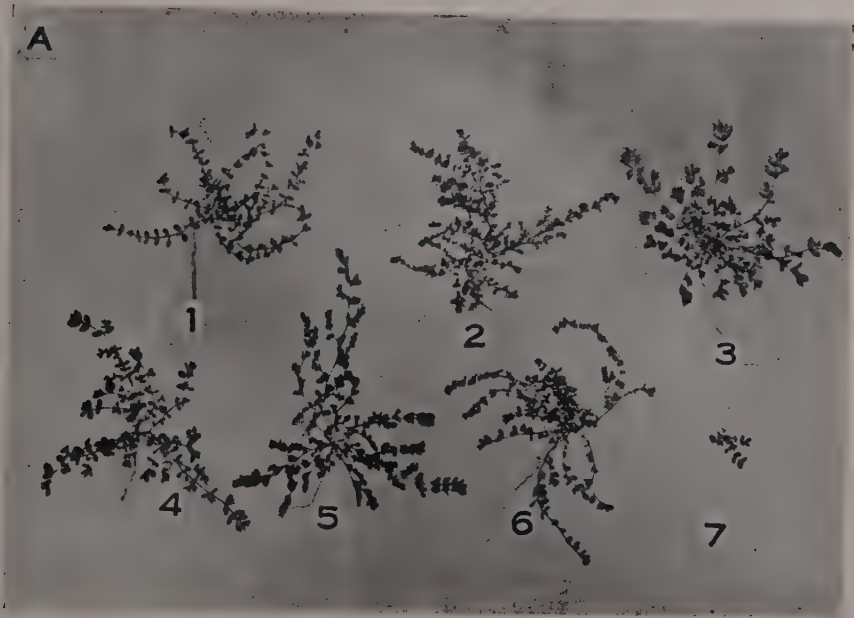
#### ACKNOWLEDGEMENTS

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#### REFERENCES

- CHANDRASEKHARAN, S. N. AND PARTHASARATHY, S. V. 1953. *Cytogenetics and Plant Breeding*. P. Varadachary & Co., Madras.
- CHRIST, H. 1897. *Das Pflanzenleben der Schweiz*. Basel.
- COOMRE, D. E. AND WHITE, F. 1951. Notes on calcicolous communities and peat formation in Norwegian Lapland. *J. Ecol.* 39: 33-62.
- DAUBENMIRE, R. F. 1947. *Plants and Environment—A Text-book of Plant Autecology*. John Wiley & Sons, Inc., New York.
- DE SILVA, B. L. T. 1934. The distribution of calcicole and calcifuge species in relation to the content of the soil in calcium carbonate and exchangeable calcium and to soil reaction. *J. Ecol.* 22: 532-51.
- EAST, E. N. 1910. A mendelian interpretation of variation that is apparently continuous. *Amer. Nat.* 44: 65-82.
- HANSON, H. C. 1958. Principles concerned in the formation and classification of communities. *Bot. Rev.* 24: 65-125.





FIGS. 1-7





- KRUCKEBERG, A. R. 1954. The ecology of serpentine soils. III. Plant species in relation to serpentine soils. *Ecology* **35**: 267-74.
- MAERZ, A. AND PAUL, R. M. 1930. *A Dictionary of Color*. McGraw-Hill Book Co., New York.
- MCVEAN, D. N. 1953. Account of *Alnus glutinosa* (L.) Gaertn. (*A. rotundifolia* Stokes) for the *Biological Flora of the British Isles*. *J. Ecol.* **41**: 447-66.
- MISRA, R. AND SIVA RAO, B. S. 1948. A study in the autecology of *Lindenbergia polyantha* Royle. *J. Indian bot. Soc.* **27**: 186-99.
- NILSSON-EHLE, H. 1908. Einige Ergebnisse von Kreuzungen bei Hafer und Weizen. *Bot. Notiser.* **108**: 257.
- PEARSALL, W. H. AND WRAY, MARJORY. 1927. The physiology and ecology of the calcifuge habit in *Eriophorum angustifolium*. *J. Ecol.* **15**: 1-32.
- PESOLA, V. A. 1928. Calcium carbonate as a factor in the distribution of plants in Finland. *Ann. (bot.-zool.) Soc. Zool.-bot. fenn. Vanamo* **9**: 246.
- RAMAKRISHNAN, P. S. 1958. Ecotypic differentiation in some plants of Varanasi. *Proc. nat. Acad. Sci. India* **28B**: 68-76.
- RAYNER, M. C. 1921. The ecology of *Calluna vulgaris*—'The calcifuge habit'. *J. Ecol.* **9**: 60-74.
- SALISBURY, E. J. 1920. The significance of calcicolous habit. *Ibid.* **8**: 202-15.
- . 1930. Mortality amongst plants and its bearing on natural selection. *Nature, Lond.* **125**: 817 and **126**: 95-96.
- . 1936. A discussion of the present state of the theory of natural selection. *Proc. roy. Soc.* **121B**: 47-49.
- *et al.* 1933. Discussion on mortality of plants and animals—Seedling mortality amongst plants. *Proc. Linn. Soc. Lond.* **145**: 97-105.
- SINGH, B. N. AND SINGH, B. L. 1938. Relative absorption of nutrients of weeds of arable land. *Soil Sci.* **47**: 227-35.
- TANSLEY, A. G. 1917. On competition between *Galium saxatile* L. (*G. hercynicum* Weig.) and *Galium sylvestra* (*G. aspernum* Schreb.) on different types of soils. *J. Ecol.* **5**: 173-79.
- WALKER, R. B. 1954. The ecology of serpentine soils. II. Factors affecting plant growth on serpentine soils. *Ecology* **35**: 259-66.
- WEBB, D. A. 1947. The vegetation of Carrokeel, a limestone hill in north-west Ireland. *J. Ecol.* **35**: 105-29.
- WHITTAKER, R. H. 1954. The ecology of serpentine soils. IV. The vegetational response to serpentine soils. *Ecology* **35**: 275-88.

## EXPLANATION OF PLATE II

- FIG. A. The red form growing in soils with different levels of calcium in the soil. 1 to 7—increasing amount of exchangeable calcium.  $\times \frac{1}{3}$  nat. size.
- FIG. B. The green form growing in soils with different levels of calcium in the soil. 1 to 7—increasing doses of exchangeable calcium.  $\times \frac{1}{3}$  nat. size.



# LEAF ANALYSIS AS A MEANS OF CROP NUTRITION STUDIES

## II. Effect of Potash Supply on the Growth, Yield and Composition of *Hordeum vulgare* L.

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### INTRODUCTION

In earlier contributions (Ranjan and Das, 1957 and Das, 1959) the author has already emphasised the importance of leaf analysis as a means of crop nutrition studies. In the present investigations also nutrient concentration of the leaf has been taken as an index of their availability in the soil.

A mass of literature exists on the effect of potassium fertilizer on various aspects of growth and nutrient uptake by the plants. Hartt (1929) was able to secure a gradation in growth of sugarcane correlated with the gradation in the amount of potassium supplied. It was noticed by Harrison (1929) that for maize potash exhibited depressing effects. On the other hand Wadleigh (1939) found that the growth of cotton plants was directly related to the level of potassium. Working on oats McClelland (1931) had shown that potash alone gave no benefit. James (1930) conducted field experiments and noticed that there was a decrease in leaf number with potassium treatment and Raheja and Misra (1955) reported that potassium sulphate applications depressed tillering. Studies on growth and yield response with potassium singly and in combination with other fertilizers had been performed by Colwell (1947), Lal and Prasad (1947), Dunton (1949), Lal and Subba Rao (1952), Chandnani (1954), etc.

Smith and Butler (1921) working on the relation of potassium to growth of wheat and corn plants in nutrient solutions found that the potassium absorbed per gram of dry matter formed was higher in plants growing in the presence of potassium than in the plants growing in its absence. Working on several kinds of plants Bartholomew and Janssen (1929, 1931) have reported many interesting findings on the absorption and utilization of potassium. Schertz (1929) found that with fertilizers high in potash, potato leaves contained the least potash while cotton leaves contained most potash. Pettinger (1931) found that potassium in the plant showed nearly perfect correlation with potassium fertilization. In a greenhouse study of the absorption of potassium by barley and tomato plants Hoagland and Martin (1933) established a high correlation

between the percentage of potassium in the dried vegetative tissue and the response of the plant to the potassium fertilization. Rajagopal and Iyengar (1938) reported that potash treatment did not give consistently striking increases in K concentration. Studies on the effect of potassium on the growth status and metabolism of tomato plant had been reported by Wall (1940) who stressed that potassium-deficient plants were characterised by a much higher nitrogen content than plants receiving the complete nutrients. Cooil (1948) reported that large differences in the tissue contents of potassium were produced by variations in the potassium concentration of the nutrient solution. Studies on the mineral content of barley plants in relation to potassium deficiency had been made by Goodall (1948) wherein he found a correlation between the increases in grain yields due to potash application and K content of older leaf blade. According to Krantz and Chandler (1951) the uptake of potash and nitrogen increased by potash and nitrogen application respectively.

#### MATERIAL AND METHODS

Experiments were conducted under field conditions on sandy loam soil of the Farm. *Hordeum vulgare* L. (Barley) var. C. 251 was grown receiving sulphate of potash at five different levels, 35 days after sowing of the seeds. The plan of the experiment was laid out after the simple replicated design, with four blocks each subdivided into six plots to accommodate all the treatments. The treatments were 20, 40, 60, 80 and 100 lb. of  $K_2O$  per acre apart from the no fertilizer treatment which served as a control. The growth record for morphological characters such as height, tiller number, leaf number, leaf area and leaf and stem dry weight were collected at three stages in the life-cycle of the plants synchronising approximately the three physiological stages. These were tillering, heading and milky grain stages falling at 50, 70 and 90 days respectively from the date of sowing. Five plants were selected at random from each plot at each sampling date for recording the above-mentioned data.

The number and weight of ear per plant, length, spikelet number and number of grains per ear as also test weight of grains were recorded at the time of harvest. The final yield of grain and straw were also taken.

For leaf analysis fully developed, healthy and green leaves of approximately the same age and expansion were collected at all the three physiological stages. These leaves were washed free of adhesive particles and dried in an oven at  $80^{\circ}C$ ., powdered and stored in airtight bottles to be used for the determination of nitrogen, phosphorus and potassium. Nitrogen was estimated by the Gunning method (A.O.A.C., 1945); phosphorus by the colorimetric micro method (A.O.A.C., 1945) and potassium by the cobaltinitrite method (Piper, 1944). Data were statistically analysed. Analysis of variance was done and 'F' test was employed to evaluate the significance in each case.

## EXPERIMENTAL RESULTS

Potash treatments did not exert any significant influence on the vertical growth of the plants at the vegetative stage but at the heading and milky grain stages it was significant (Table I). Maximum height was recorded in 20 K\* treatment at the vegetative stage but beyond this

TABLE I

*The effect of potassium dressings on the growth characters of barley plant at different physiological stages in its life-cycle*

Growth stages		K <sub>2</sub> O lb./acre						S.E.	C.D. 5%	C.D. 1%
		0	20	40	60	80	100			
		Vertical growth (height in cm.)								
Vegetative	..	39.69	43.27	40.31	38.58	40.07	37.67	1.463	4.408	6.096
Heading	..	60.96	65.02	68.80	62.83	59.78	61.00	1.663	5.011	6.920
Milky grain	..	90.24	93.64	94.07	84.09	80.69	80.04	2.307	6.951	9.613
		Tiller number (per plant)								
Vegetative	..	3.05	3.40	3.45	2.80	2.65	2.70	0.206	0.621	0.858
Heading	..	3.60	3.80	3.95	3.20	2.75	2.85	0.254	0.765	1.058
Milky grain	..	2.70	3.05	3.20	2.70	2.40	2.25	0.239	0.720	0.995
		Leaf number (per plant)								
Vegetative	..	12.20	14.20	14.70	12.00	11.60	11.95	1.289	3.884	5.371
Heading	..	14.50	16.65	15.65	12.85	11.25	11.00	0.883	2.261	3.679
Milky grain	..	10.25	12.30	10.75	11.45	9.27	8.30	0.676	2.036	2.816
		Foliage expansion (area, sq. cm./plant)								
Vegetative	..	193.25	217.93	225.91	170.33	179.44	145.14	18.053	54.397	75.227
Heading	..	248.93	283.15	269.61	205.45	179.19	193.04	24.700	74.470	102.943
Milky grain	..	234.35	253.23	225.48	222.85	176.60	153.91	17.590	53.030	73.303

there was a gradual fall up to 100 K. At the heading and milky grain stages there was a rise up to 40 K and beyond it a depressing effect was noted on the height of the plants. Potash treatments had a significant effect on the rate of tiller production at the vegetative stage where an increase up to 40 K was noted and beyond this there was a decline in

\* 20 K, 40 K, 60 K, 80 K and 100 K stand for 20, 40, 60, 80 and 100 lb. of K<sub>2</sub>O per acre respectively.



tiller number (Table I). At the heading stage the increase in tiller number from control up to 40 K treatment was insignificant. The depression in 80 K and 100 K was also insignificant. There was a reduction in tiller number at the milky grain stage as compared to earlier stages. Number of leaves per plant exhibited a significant treatment effect at the heading and milky grain stages whereas at the vegetative stage it was insignificant (Table I). A rise in leaf number was recorded in 20 K and 40 K treatments as against control at the vegetative stage and thereafter a decline. At the heading stage maximum leaf number was noted in 20 K. At the milky grain stage also maximum leaf number was seen in 20 K treatment. There was no significant effect of potash treatment on the foliage expansion at the vegetative stage (Table I). An increase in leaf area was recorded from control up to 40 K treatment. Higher doses led to a reduction in leaf area. At the heading stage maximum leaf expansion was recorded in 20 K and doses higher than this and up to 100 K showed lower area. At the milky grain stage in general there was a decrease in leaf area as compared to heading stage. Maximum foliage expansion was noted in 20 K and minimum in 100 K treatment.

The effect of potash treatment on the leaf dry matter accumulation was statistically insignificant at all the three stages (Table II). In general there was a slight increased leaf dry matter accumulation in 20 K treatment but further additions of potash led to a decrease in the leaf weight. With regard to the stem dry matter accumulation the treatment effect was statistically significant at the heading and milky grain stages (Table II). At the vegetative stage a gradual fall from control up to 60 K was noticed. At the heading stage maximum stem dry matter accumulation was found in 40 K treatment and it was significantly higher than control. At the milky grain stage maximum stem dry matter had been recorded in 20 K whereas 60, 80 and 100 K treatments brought about a significant depression.

Number of ears per plant showed a significant decrease in 60, 80 and 100 K treatments over that of control (Table III). Weight of ears per plant indicated an insignificant rise in 20 K treatment over that of control but further higher doses led to a significant depression. There was no significant treatment effect on the length of ears. A rise in 20 K was seen as compared to control but further higher dressings of potash decreased ear length. Maximum number of spikelets per ear was recorded in 20 K treatment and minimum in 100 K treatment. A rise in grain number per ear was noticed from control up to 40 K treatment. Further higher additions of fertilizer decreased the grain number and minimum was recorded in 100 K. Absolute weight of grains recorded a rise in 20 K, then a subsequent fall up to 60 K and again a slight increase in 80 and 100 K treatments.

Grain yield was significantly affected by potash dressings (Table IV). Maximum and significantly higher yield was recorded in 20 K than in control. With higher applications of the fertilizer a gradual fall in grain yield was recorded which was significantly so in 60 K and higher

TABLE II

*The effect of potassium dressings on the dry matter accumulation of barley plant at different physiological stages in its life-cycle*

Growth stages		K <sub>2</sub> O lb./acre						S.E.	C.D. 5%	C.D. 1%
		0	20	40	60	80	100			
		Leaf dry matter (weight, gm./plant)								
Vegetative	..	0.571	0.608	0.563	0.518	0.468	0.591	0.039	0.117	0.162
Heading	..	0.630	0.674	0.666	0.554	0.505	0.565	0.047	0.141	0.195
Milky grain	..	0.775	0.845	0.798	0.669	0.654	0.708	0.049	0.149	0.205
		Stem dry matter (weight, gm./plant)								
Vegetative	..	0.535	0.445	0.430	0.371	0.431	0.446	0.037	0.111	0.154
Heading	..	0.746	0.923	1.045	0.674	0.677	0.763	0.049	0.147	0.204
Milky grain	..	2.071	2.345	2.004	1.936	1.473	1.513	0.166	0.500	0.691

TABLE III

*The effect of potassium dressings on the ear characters of barley*

Characters	K <sub>2</sub> O lb./acre						S.E.	C.D. 5%	C.D. 1%
	0	20	40	60	80	100			
Ears/plant (No.)	2.80	3.15	3.05	2.50	2.15	2.40	0.195	0.588	0.813
Ear weight (gm./plant)	3.57	3.87	3.75	2.88	2.78	3.04	0.245	0.738	1.021
Ear length (cm.)	15.88	16.35	15.97	15.71	16.21	16.12	0.300	0.904	1.250
Spikelet No. (per ear)	10.76	11.72	10.93	10.62	11.25	10.10	0.458	1.380	1.908
Grain No./ear	25.73	27.15	27.56	26.05	26.78	25.38	0.947	2.853	3.946
Grain weight (absolute, gm.)	40.70	41.68	40.87	39.62	41.30	40.61	0.518	1.560	2.158

treatments as compared to 20 K. Straw yield had also been maximum in 20 K treatment although there was no significant increase as compared to control (Table IV). Further higher additions of potash had significantly lowered straw production and minimum was recorded in 100 K. The straw/grain ratio recorded a fall from control up to 40 K treatment. Higher potash treatments had higher straw/grain ratio.

The uptake of nitrogen, as revealed by leaf analysis, had been significantly affected only at the vegetative and heading stages (Table V).

TABLE IV

*Grain and straw yield of barley as affected by potassium dressings  
(lb./acre)*

Yield	K <sub>2</sub> O lb./acre						S.E.	C.D. 5%	C.D. 1%
	0	20	40	60	80	100			
Grain ..	788.37	1031.03	1001.15	788.82	676.40	682.20	51.41	154.91	214.22
Straw ..	2030.86	2193.00	1987.30	1919.05	1931.64	1819.83	57.75	174.04	240.68
Straw/grain	2.57	2.13	1.98	2.60	2.87	2.66	..	..	..

TABLE V

*Effect of potassium dressings on leaf composition at different physiological  
stages of growth of barley plant  
(oven-dry basis gm. per 100 gm.)*

Growth stages	K <sub>2</sub> O lb./acre						S.E.	C.D. 5%	C.D. 1%
	0	20	40	60	80	100			
Nitrogen (N)									
Vegetative ..	2.830	2.950	3.155	2.600	2.750	2.600	0.091	0.276	0.381
Heading ..	4.400	4.100	4.200	4.500	4.450	4.605	0.103	0.312	0.431
Milky grain ..	3.800	4.005	4.055	4.020	3.820	3.700	0.086	0.261	0.361
Phosphorus (P <sub>2</sub> O <sub>5</sub> )									
Vegetative ..	0.3840	0.4839	0.3370	0.3542	0.3882	0.3553	0.0100	0.0301	0.0416
Heading ..	0.5494	0.6106	0.4015	0.3787	0.3998	0.3647	0.0102	0.0307	0.0425
Milky grain ..	0.3863	0.4784	0.5197	0.5398	0.4621	0.4171	0.0196	0.0882	0.1220
Potassium (K <sub>2</sub> O)									
Vegetative ..	4.192	3.809	3.973	3.754	3.993	4.305	0.123	0.372	0.515
Heading ..	4.408	4.898	3.720	3.530	3.435	3.624	0.105	0.318	0.440
Milky grain ..	3.354	3.570	3.278	3.156	3.044	2.755	0.089	0.270	0.374

A significant rise in nitrogen uptake was found from control up to 40 K treatment. Further higher applications of potash led to lower nitrogen percentage in the leaves. At the heading stage higher doses

led to more of nitrogen uptake than lower doses of 20 K and 40 K treatments. At the milky grain stage a slight rise in 20 K and 40 K was found but in higher treatments there was a gradual decline in leaf nitrogen percentage. With increase in age, there was a rise in leaf nitrogen in all the treatments up to the heading stage when plants were 70 days old but after this a decline was seen in all the treatments.

At the vegetative stage the uptake of phosphoric acid showed a significant rise in 20 K treatment but addition of more potash lowered the leaf values (Table V). At the heading stage a significant rise in  $P_2O_5$  uptake was noted in 20 K over control but higher doses of 60, 80 and 100 K recorded significantly lower values. At the milky grain stage there was a rise from control up to 60 K treatment in the uptake of  $P_2O_5$  by the plants and beyond this treatment a fall was recorded. As far as the effect of age on  $P_2O_5$  uptake is concerned it was seen that in the lower doses the uptake continued only up to heading stage and thereafter a fall but in higher treatments it continued up to the milky grain stage.

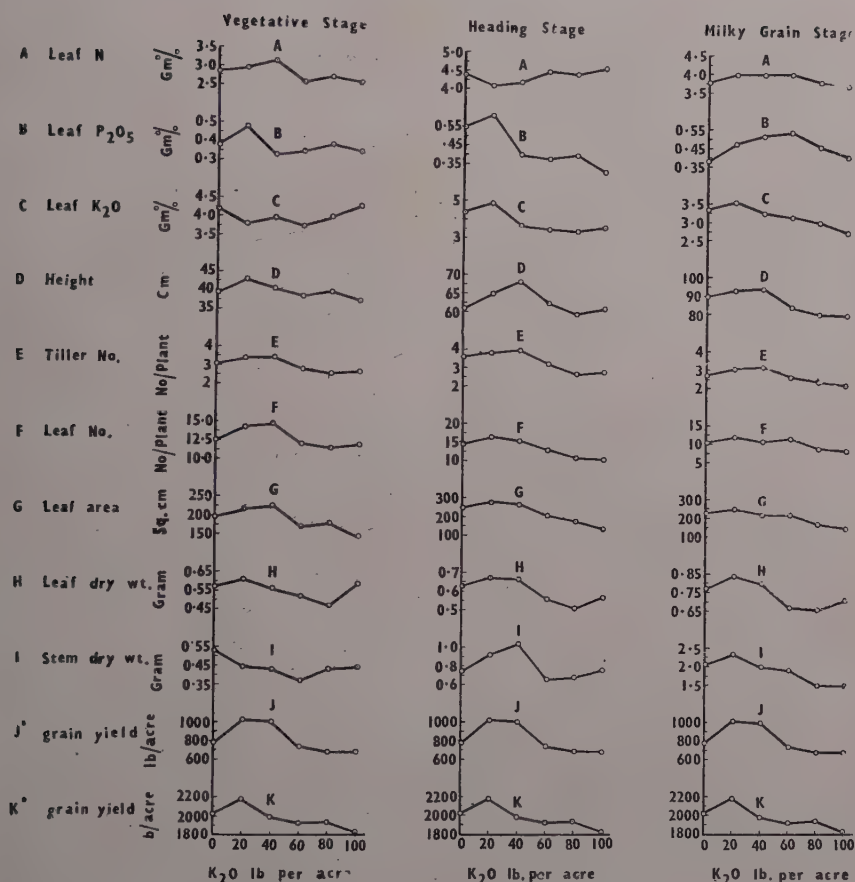
The effect of potassium sulphate dressings on the uptake of potash showed a depression in 20 K treated plants at the vegetative stage (Table V). There was no regular trend in the potash uptake in higher treatments although 100 K recorded maximum and significant value as compared to 20 K. At the heading stage maximum potash was noticed in the lowest treatment of 20 K. Higher treatments had highly significant low leaf potash values. At the milky grain stage 20 K showed an increased  $K_2O$  uptake over control but beyond this treatment there was a gradual decrease in leaf values with increase in dosage.

### DISCUSSION

Potassium fertilizer led to a slightly increased linear growth in lower treatments (Text-Fig. 1, D) but Lal and Prasad (1947) did not find increase in height at low potash treatments. At higher doses there was a depressing effect on this character. Similar results were also found for tiller and leaf number (Text-Fig. 1, E and F). A fall in leaf number was also reported by James (1930) with potash application. It seems that meristematic activity was very low in higher treatments due to which growth was poor. A decrease in the nutrient content of the leaves was also seen which was probably responsible for the poor growth in higher potash treated plants. The foliage expansion recorded increased values only in lower treatments and that too at the vegetative and heading stages (Text-Fig. 1, G). Thus, it seems that there was some favourable effect at lowest dose of  $K_2O$  at the earliest stages of growth but later on there was none (James, 1930).

Dry weight of the leaf and stem also did not show any appreciable rise (Text-Fig. 1, H and I). The leaf and stem dry matter accumulation recorded a rise only at the lower doses of potash treatment. Higher doses led to a significant decrease which indicated detrimental effect of higher potash application. Wall (1940) had also reported a decline





TEXT-FIG. 1. Effect of potassium application on growth and leaf composition at different physiological stages and final yield of barley.

\* For ready reference and easy comparison, the curves for final grain and straw yield have been given under all the stages.

in growth curve with increase in potassium above a certain amount. Hartt (1929) had reported a correlation in growth with the amount of potash supply but no such correlation was found here probably due to presence of sufficient potash in the soil.

At the vegetative stage, the height of the plants increased along with an increase in tiller and leaf number in all the treatments (Text-Fig. 1, cf. D with E and F). The increase in tiller and leaf number was associated with meristematic activity; the division of shoot meristems, leading to increased number of growing points; the rate of production of tiller primordia and leaf primordia. The increase in leaf nitrogen was also

noticed at this stage which indicated that the utilization of nitrogen was favourably affected up to 40 K treatment (Text-Fig. 1, A).

Vertical growth of the plants was correlated with ear characters especially ear number up to 60 K treatment. There was a strong correlation between leaf number and tiller number in all the treatments (Text-Fig. 1, *cf.* E and F). At the heading stage of the plant's life-cycle many growth characters showed correlation. The height of the plants was found to be correlated with tiller number, leaf number and leaf dry weight in all the treatments (Text-Fig. 1, *cf.* D with E, F and H). The tiller number as also the leaf number had practically the same trend in all the treatments (Text-Fig. 1, *cf.* E and F). This similarity was associated with meristematic activity of the plants. The treatments which favoured tillering also favoured the development of new leaves by the initiation of newer primordia. Tiller number and stem dry weight on the one hand and leaf number and leaf dry weight on the other hand also exhibited a correlation at the heading stage (Text-Fig. 1, *cf.* E with I and F with H).

At the final stage of growth record when plants were in the milky grain stage a correlation was observed between height and tiller number at all the doses. The leaf number and leaf area also had a similar trend in all the treatments (Text-Fig. 1, D to G). The height of the plants was also correlated with increase in leaf area (Text-Fig. 1, *cf.* D and G). The tiller number and leaf number recorded almost the same trend in all the different treatments which indicated that the formation of leaf and stem primordia go hand in hand (Text-Fig. 1, *cf.* E and F). Leaf number and leaf dry weight had a positive correlation at all the doses. The leaf weight and stem weight at the final stage of growth were also correlated; with increase in leaf weight there was an increase in stem weight while a decrease in leaf weight was associated with a decrease in stem weight in all the treatments (Text-Fig. 1, *cf.* H and I). Thus, it may be said that the leaf production controls the dry matter accumulation in the stem as it is the centre of metabolic activities.

Almost all the ear characters were unfavourably affected by potash treatments. Ear number per plant showed a slight rise in 20 K treatment but higher treatments led to a reduction (Table III). Similar reduction was also noted in tiller number which explains the trend noted in ear number. Absolute weight of grains had increased with 20 K treatment but further higher treatments decreased the value. The decrease in most of these characters was due to low nitrogen and phosphoric acid uptake as revealed by leaf analysis (Text-Fig. 1, A and B). This decrease in uptake was because the soil was deficient in both these nutrients essential for the healthy growth of the plants.

Grain yield increased in 20 K and 40 K treatments but higher treatments had significantly lower yield (Dunton, 1949). Straw yield had also been adversely affected by potash treatments, except 20 K treatment which showed an increase over control (Text-Fig. 1, K). The straw/grain ratio was minimum in 40 K which indicated that this treatment had favoured the production of grain more than that of straw. Thus it seems that high doses of  $K_2O$  without N and  $P_2O_5$  had a detrimental

effect on almost all aspects of plant growth. McClelland (1931) did not find any benefit with potash application. Alov (1944) also found that increased addition of K during stooling reduced production of grain and straw.

The uptake of nitrogen at the vegetative stage was found to rise in lower treatments but higher treatments led to a decrease in nitrogen uptake (Text-Fig. 1, A). When compared with potash (Text-Fig. 1, C), it was seen that with an increase in potash uptake there was a corresponding decrease in nitrogen uptake. Thus high percentage of K in the plant was correlated with low percentage of nitrogen (Janssen and Bartholomew, 1929). At the heading stage the decrease in nitrogen in 20 K and 40 K treatments was partly due to the soil being deficient in nitrogen and partly due to the reciprocal effect of  $K_2O$  on nitrogen uptake. Further higher treatments of potash slightly increased nitrogen percentage while it decreased the  $K_2O$  percentage which further supported the above findings. The decrease at the last stage was probably due to translocation of nitrogen to the grains although grain yield was not much affected. The nitrogen values, in general, were quite low due to which poor growth and low yield resulted.

Phosphoric acid uptake was also found to decrease with increasing doses of potash with the exception of 20 K where an increased uptake was noticed (Text-Fig. 1, B). Thus it seems that the uptake of phosphoric acid was checked to some extent by potash fertilizers although Samuels and Capo (1952) did not find consistent effect of potassium addition on phosphorus concentration. Wall (1940) had also reported high phosphorus content in the low potassium plants. Moreover, soil was also deficient in phosphate. Eriksson (1942) had also found a decrease in P uptake due to K manuring. There was, however, no change in the trend of phosphoric acid at the heading stage although the percentage had increased. At the milky grain stage a slight change in the trend of phosphoric acid uptake had been recorded. Here the amount of  $P_2O_5$  in the leaf of 40 K and 60 K treatments was higher than the first two stages. It seems that the phosphoric acid could not be utilized for metabolic activities of the plant as was reflected by poor growth and low yield.

The uptake of potash was significantly increased by potash treatment (Text-Fig. 1, C). At the vegetative stage a rise in 80 K and 100 K treatments seemed to be in the region of luxury consumption as there was no corresponding increase in growth. On the contrary a significant depression had been recorded in these treatments. As compared to the amount of  $K_2O$  supply to the soil very little accumulation had been recorded in all the treatments. At the heading stage, except for a rise in 20 K treatment, there was a fall in leaf  $K_2O$  values which had fallen even lower than the values at the vegetative stage in 40 K and higher treatments. Schertz (1929) had also reported that high application of potash produced leaves containing least potash, while Wall (1940) found sharp increase in potassium in the plant treated with high potash fertilizer. At the milky grain stage, except for a slight rise in 20 K treatment, there was a gradual fall and minimum value was recorded in



100 K treatment. The decrease can be attributed to two possibilities. Firstly, that after the initial uptake of  $K_2O$ , as noticed at the vegetative stage, further uptake had been checked due to resistance of potash accumulation or there might have been translocation to other parts of the plant. From the results it seems that optimum treatment was 20 lb. per acre at which maximum assimilation had taken place and above this assimilation was reduced as was evident from poor growth and low yield (Janssen and Bartholomew, 1929).

The poor growth of the potassium-treated plants as shown by low tiller number, leaf number and leaf area was due to the lack of adequate amount of available nitrogen as shown by the effect of nitrogen treatments (Ranjan and Das, 1957). Fisher (1935) noted that tomato plants grown in a culture solution deficient in nitrogen had decreased amount of protoplasm and there was a general reduction in the growth of leaves and stem. On the other hand it was found by Das (1936) that increasing the application of nitrogen to sugarcane increased the leaf area, rate of leaf and joint formation, rate of stem elongation and tillering. The amount of nitrogen in the leaf was also low and rose only up to 40 K treatment while higher doses had very low nitrogen values. The phosphorus in the potash-treated plants was very low which was also a factor responsible for poor meristematic activity. The low value was recorded due to the lack of phosphorus available to the plants. According to Mac Gillivray's (1927) findings, high percentage of phosphorus is associated with regions of active growth and thus a lack of sufficient phosphorus leads to poor growth.

The leaf potash was found to increase with addition of potassium fertilizer to the soil, especially in the higher doses (Text-Fig. 1, C). This was due to the increased amount of available potash in the soil. Practically all the investigators including Bartholomew and Janssen (1929), Johnston and Hoagland (1929), Wallace (1931), Janssen and Bartholomew (1932), Wallace and Proebsting (1933) and Hartt (1934) had also reported that the amount of potassium in the plant is increased by its application to the soil. In many of these observations as also in the present one the luxury absorption of this element was apparent.

The nitrogen and potassium in the leaf showed an inverse relationship at all the doses (Text-Fig. 1, cf. A with C). It has also been observed by Gildehouse (1931), Janssen and Bartholomew (1932), Colby (1933), Rippel *et al.* (1933) and Ranjan and Das (1957) that the amount of nitrogen was markedly higher in those treatments that had been grown in a sufficient supply of this element. Janssen *et al.* (1934) found evidence in tomato plants that deficiency of potassium caused an accumulation of amino forms of nitrogen.

The leaf  $P_2O_5$  at the heading stage showed a decrease with increase in dosage of potash to the soil while leaf nitrogen showed a slight rise in these treatments. Leaf phosphorus at the heading stage showed a correlation with the straw yield in almost all the treatments (Text-Fig. 1, cf. B with K). With increase in leaf  $P_2O_5$  a corresponding increase in straw yield was noted. As phosphorus plays a positive role in the



metabolic processes, therefore, a reduction in phosphorus leads to many of the physiological processes being retarded and consequently a fall in straw yield. Similar correlations have also been reported under phosphate treatments (Das, 1956, 1959).

#### SUMMARY

Barley (*Hordeum vulgare*, var. C. 251) was grown on sandy loam soil under field conditions. Sulphate of potash was applied at five different levels, viz., 20, 40, 60, 80 and 100 lb. of  $K_2O$  per acre. Along with these a no-treatment control was also run. The entire experiment was laid out statistically and all the data were subjected to statistical analysis. Height, tiller number, leaf number, leaf area, leaf and stem dry weight were recorded at three physiological stages, viz., vegetative, heading and milky grain falling at 50, 70 and 90 days respectively from the date of sowing. At these very stages leaf was also analysed for nitrogen, phosphorus and potassium content. Finally ear characters and yield of grain and straw were also recorded.

In general vegetative characters such as height, leaf and tiller number and leaf area increased up to a treatment of 40 lb.  $K_2O$  per acre whereas ear characters and final straw and grain yield recorded an increase only in 20 lb.  $K_2O$  per acre treatment. Further higher doses led to marked fall in most of the characters. The response to potash application indicated that the soil under investigation needs only very low dose of  $K_2O$  for better growth and yield.

The effect of potash application on growth and nutrient uptake at different physiological stages and the final yield have been discussed on the basis of leaf composition. Several correlations have been found to exist between growth characters as well as with the nutrient composition of the leaf. A high percentage of  $K_2O$  in the leaf was correlated with a low percentage of N in the leaf. Leaf  $P_2O_5$  also showed a positive correlation with the final straw yield.

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#### REFERENCES

- ALOV, A. 1944. Sootnoshenie azota i kalia v pitanii zernovikh kultur v processe rosta (The N/K ratio in the nutrition of cereals at different stages of growth). *Proc. Lenin Acad. agric. Sci.* 1: 31-38.
- A.O.A.C. 1945. *Methods of Analysis of the Association of Official Agricultural Chemists*. Association of Official Agricultural Chemists, Washington D.C.
- BARTHOLOMEW, R. P. AND JANSSEN, G. 1929. The relation between concentration of potassium in culture solutions and optimum growth. *Soil Sci.* 27: 189-203.
- . 1931. The rate of absorption of potassium by plants and its possible effect upon the amount of potassium remaining in soils from applications of potassium fertilizers. *Bull. Ark. agric. Exp. Sta.* 265: 1-72.

- CHANDNANI, J. J. 1954. Manuring of wheat. *Indian J. agric. Sci.* **24**: 195-96.
- COLBY, H. L. 1933. Effect of starvation on distribution of mineral nutrients in French prune trees grown in solution cultures. *Plant Physiol.* **8**: 357-94.
- COLWELL, W. E. 1947. Studies on the effect of nitrogen, phosphorus and potash on the yield of corn and wheat in Mexico. *Proc. Soil Sci. Soc. Amer.* **11**: 332-40.
- COOIL, B. J. 1948. Potassium deficiency and excess in Guayule. I. Growth responses and mineral content. *Plant Physiol.* **23**: 286-308.
- DAS, N. 1956. Role of phosphate in plants. *Proc. nat. Acad. Sci. India* **25 A**: 476-78.
- . 1959. Leaf analysis as a means of crop nutrition studies. I. Effect of phosphate supply on the growth, yield and composition of *Hordeum vulgare* L. *J. Indian bot. Soc.* **38**: 338-52.
- DAS, U. K. 1936. Nitrogen nutrition of sugarcane. *Plant Physiol.* **11**: 251-317.
- DUNTON, H. L. 1949. The effect of varying the treatments of nitrogen, phosphorus and potassium alone and in combination on certain characteristics of dwarf grain sorghum. *Dissertation*, University of Michigan, 1-72.
- ERIKSSON, S. 1942. Untersuchungen über die einwirkung von Kalisalzen auf die löslichkeit der Bodenphosphorsäure. *K. Landtber. Akad. Handl. Stockh.* **81**: 1-101.
- FISHER, P. L. 1935. Response of the tomato in solution cultures with deficiencies and excesses of certain essential elements. *Bull. Md. agric. exp. Sta.* **375**: 283-98.
- GILDEHAUS, E. J. 1931. The relation of nitrogen to potassium in the nutrition of fruit trees. *Bot. Gaz.* **92**: 384-95.
- GOODALL, D. W. 1948. Studies in the diagnosis of mineral deficiency. IV. The mineral content of barley plants in relation to potassium deficiency. *Ann. appl. Biol.* **35**: 605-23.
- HARRISON, W. H. 1929. Notes on permanent experimental plots at Pusa. *Proc. Bd agric. India App.* **I**: 225-34.
- HARTT, C. E. 1929. Potassium deficiency in sugarcane. *Bot. Gaz.* **88**: 229-61.
- . 1934. Some effects of potassium upon the growth of sugarcane and upon the absorption and migration of ash constituents. *Plant Physiol.* **9**: 399-451.
- HOAGLAND, D. R. AND MARTIN, J. C. 1933. Absorption of potassium by plants in relation to replaceable, non-replaceable and soil solution potassium. *Soil Sci.* **36**: 1-32.
- JAMES, W. O. 1930. Studies of the physiological importance of the mineral elements in plants. I. The relation of potassium to the properties and functions of the leaf. *Ann. Bot., Lond.* **44**: 173-98.
- JANSSEN, G. AND BARTHOLOMEW, R. P. 1929. The translocation of potassium in tomato plants and its relation to their carbohydrate and nitrogen distribution. *J. agric. Res.* **38**: 447-65.
- . 1932. The effect of potassium on the production of proteins, sugar and starch in cow-pea and in sugar-beet plants and the relation of potassium to plant growth. *J. Amer. Soc. Agron.* **24**: 667-70.
- AND WATTS, V. M. 1934. Some effects of nitrogen, phosphorus and potassium on composition and growth of tomato plants. *Bull. Ark. agric. exp. Sta.* **310**.
- JOHNSON, E. S. AND HOAGLAND, D. R. 1929. Minimum potassium level required by plants grown in water cultures. *Soil Sci.* **27**: 89-108.

- KRANTZ, B. A. AND CHANDLER, W. V. 1951. Lodging, leaf composition and yield of corn as influenced by heavy application of nitrogen and potash. *J. Amer. Soc. Agron.* **43**: 547-52.
- LAL, K. N. AND PRASAD, G. 1947. Studies in crop physiology—Growth characters and seed quality in wheat as influenced by nitrogen, phosphoric acid and potash. *Proc. nat. Acad. Sci. India* **17**: 83-94.
- AND SUBBA RAO, M. S. 1952. Studies in crop physiology—Effect of N.P.K. ratios on growth characters of barley. *J. Indian bot. Soc.* **31**: 217-39.
- MAC GILLIVARY, J. H. 1927. Effect of phosphorus on composition of tomato plant. *J. agric. Res.* **34**: 97-127.
- MCCLELLAND, C. K. 1931. Effect of various plant food on growth activities and development of oats. *J. Amer. Soc. Agron.* **23**: 304-11.
- PETTINGER, A. N. 1931. The expressed sap of corn plants as an indicator of nutrient needs. *J. agric. Res.* **43**: 95-119.
- PIPER, C. S. 1944. *Soil and Plant Analysis*. The University of Adelaide, Adelaide.
- RAHEJA, P. C. AND MISRA, M. D. 1955. Development studies in crop plants. I. Influence of nitrogen, phosphate, potash and calcium alone and in combination on wheat. *Indian J. agric. Sci.* **25**: 87-104.
- RAJAGOPAL, S. AND IYENGAR, A. V. 1938. Studies on the chemical composition and physiological properties of plant tissue fluids. II. Effect of mineral fertilizers on the tissue fluids of ragi (*Eleusine coracana* Linn.). *J. Indian Inst. Sci.* **21A**: 103-13.
- RANJAN, S. AND DAS, N. 1957. Effect of nitrogen supply on nutrient uptake as revealed by leaf analysis and on the growth and yield of *Hordeum vulgare* L. *Proc. nat. Acad. Sci. India* **27B**: 227-34.
- RIPPEL, A., BEHR, G. AND MEYER, R. 1933. Zur Kenntnis der Wirkung des Kaliums auf höhere Pflanzen. *Z. Pflernähr. Düng.* **32**: 95-109.
- SAMUELS, G. AND CAPO, B. G. 1952. Effects of a level of fertilizer element on the uptake and concentration of that element and other elements in a plant. *J. Amer. Soc. Agron.* **44**: 352-57.
- SCHERTZ, F. M. 1929. The effect of potassium, nitrogen and phosphorus fertilizing upon chloroplast pigments, upon the mineral content of the leaves, and upon production in crop plants. *Plant Physiol.* **4**: 269-79.
- SMITH, T. O. AND BUTLER, O. 1921. Reaction of potassium to growth in plants. *Ann. Bot., Lond.* **35**: 189-225.
- WADLEIGH, C. H. 1939. The influence of varying cation proportions upon the growth of young cotton plants. *Soil Sci.* **48**: 109-20.
- WALLACE, T. 1931. Chemical investigations relating to potassium deficiency of fruit trees. *J. Pomol.* **9**: 111-21.
- AND PROEBSTING, E. L. 1933. The potassium status of soils and fruit plants in some cases of potassium deficiency. *Ibid.* **11**: 120-48.
- WALL, M. E. 1940. The role of potassium in plants. I. Effect of varying amounts of potassium on the growth status and metabolism of tomato plants. *Soil Sci.* **49**: 315-31.

# RECURRENCE OF DROUGHT CONDITIONS AND MORTALITY IN SAL FORESTS OF UTTAR PRADESH

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SAL (*Shorea robusta*) forests of Uttar Pradesh occur in a climatic region which is regarded as semi-moist. Slight climatic variations, as usually prevail in a monsoon type of climate, upset the delicately balanced soil-water regime, which is so essential for the well being of sal forests. The recurrence of drought conditions, therefore, affects the growth and reproductive capacity of sal forests to a varying extent.

The climatic records of the last eighty years indicate that severe drought conditions prevailed in 1877, 1883, 1907, 1918 and 1928. The years 1877 and 1918 were also the worst famine years. Drought in a milder form is of more frequent occurrence, when deficient rainfall and intense summer heat years coincide. But the chances of one drought year being succeeded by another in a particular area appear to be small. The recurrence of severe drought years is given in Table I, for the whole of India. This analysis indicates that the belt constituted by Kashmir, East and North Punjab, East and West Uttar Pradesh and Bihar are most liable to such climatic adversities.

The early history of the sal forests of Uttar Pradesh is not precisely known, particularly in relation to drought damage. The first attempt to assess the causes and effects of drought damage was made by Troup (1913), in respect of the drought which occurred in 1907.

It was realised that the immediate effects of drought on tree vegetation are often imperceptible. However, once the damage sets in, it lingers for an abnormally long period. The death of sal trees is caused gradually. During this period of natural calamity, recurrence of even a mild type of drought conditions aggravates the damage. If drought conditions occur in successive years, the damage assumes severe magnitude and extends far and wide. In the initial stages, drought damage is confined to hills and silty plains where the sites have the minimum water-holding capacity. The young plants of sal, on which depends the perpetuity of the existing sal forests, receive the first and severest blow. Coppice growth of sal is equally liable to this kind of damage.

Seth (1954) pointed out that there are two cycles of drought damage. One cycle exhibits long-term effects. Its causative factors are climatic and ecological in origin. It leads to gradual xerophytism and consequent



TABLE I  
Showing number of drought years from 1875 to 1944

Regions	No. of severe drought years	Actual years
Assam .. ..	3	1884, 1896, 1900
Bengal .. ..	3	1884, 1891, 1895
Orissa .. ..	2	1901, 1924
Chhota Nagpur ..	2	1903, 1915
Bihar .. ..	8	1877, 1882, 1884, 1891, 1901, 1903, 1908, 1932
U.P. East .. ..	7	1877, 1880, 1883, 1896, 1907, 1918, 1928
U.P. West .. ..	8	1877, 1883, 1905, 1907, 1913, 1918, 1928, 1941
Punjab East and North ..	8	1877, 1883, 1889, 1911, 1915, 1918, 1920, 1939
Punjab South and West ..	3	1899, 1904, 1915
Kashmir .. ..	9	1902, 1904, 1907, 1911, 1912, 1915, 1918, 1920, 1937
Rajputana West ..	7	1877, 1899, 1905, 1911, 1915, 1918, 1939
Rajputana East ..	4	1877, 1905, 1915, 1918
Gujarat .. ..	6	1877, 1899, 1904, 1911, 1915, 1918
Central India West ..	3	1877, 1915, 1918
Central India East ..	4	1877, 1905, 1913, 1918
Berar .. ..	4	1880, 1899, 1918, 1920
Madhya Pradesh West ..	7	1877, 1886, 1899, 1904, 1918, 1920, 1941
Madhya Pradesh East ..	4	1899, 1902, 1920, 1941
Konkan .. ..	6	1877, 1899, 1905, 1918, 1920, 1941
Bombay Deccan ..	4	1899, 1905, 1911, 1918
Hyderabad North ..	4	1877, 1899, 1918, 1920
Hyderabad South ..	5	1876, 1877, 1899, 1918, 1920
Mysore .. ..	1	1918
Malabar .. ..	3	1881, 1899, 1918
Madras South-East ..	5	1884, 1891, 1918, 1923, 1934
Madras, Deccan ..	4	1877, 1884, 1891, 1922
Madras Coast North ..	1	1920

annual mortality. The other cycle is a short-term one, and is affected due to sudden variations in local climatic factors, *e.g.*, rainfall. The mortality caused is pronounced abruptly. The main role of climatic changes, leading to drought conditions and ultimate mortality in sal forests, lies in its adverse effect on the soil-moisture regime. Sudden exhaustion or disappearance of perched water-tables is more often the case.

Pande (1956) discussed drought mortality in Bahraich Division as directly correlated with rainfall and the depth of the water-table. Occurrence of two or more years of deficient rainfall is sure to induce heavy mortality. The worst period in the history of Bahraich Division appears to have been from 1911 to 1913. From 1913 to 1924 matters gradually improved, but drought damage started again in 1924 and continued up to 1932, which was again a bad year. A bad period for Chakia and Charda was 1943 to 1947. Years of deficit rainfall for Bahraich are given in Table II.

TABLE II  
*Years of deficit rainfall for Bahraich*  
(Normal rainfall—1159·8 mm.)

1860	787·4 mm.	1913	769·6 mm.
1864	609·6 ”	1918	767·1 ”
1873	820·4 ”	1928	881·4 ”
1891	873·8 ”	1929	817·9 ”
1899	891·5 ”	1932	919·5 ”
1901	998·2 ”	1941	993·1 ”
1905	967·7 ”	1946	886·5 ”
1907	467·4 ”	1950	944·9 ”
1908	683·3 ”	1951	533·4 ”
1912	820·4 ”		

The extent of drought damage in Bahraich division is given in Table III.

Sinha (1957) has dealt with the various aspects of recent mortality of sal in Gorakhpur forest division. As a result of this unusual mortality, about 30,000 sal trees were marked in 1952–53 for felling. In 1951 and 1952 the rainfall of Gorakhpur was quite deficient being 682·7 and 959·6 mm. respectively. The normal annual rainfall is 1,226·3 mm. It is, therefore, apparent that this mortality in sal was mainly due to induced drought conditions.

TABLE III

Years	Total annual rain-fall (Nanpara)	Number of trees by diameter Class in cm.			Total No. of dry and dying sal trees	Total volume of dry and dying sal trees (Vol.) units
		0-30	30-51	Over 51		
1934	1158.2	214	223	41	478	543
1935	960.1	730	733	122	1585	1447
1936	1567.2	2286	3083	610	5979	5733
1937	876.3	1269	799	170	2238	2023.5
1938	1775.5	528	301	37	866	684.5
1939	1160.8	..	..	..	..	..
1940	1010.9	2180	1076	386	3642	3298.5
1941	993.1	..	..	..	1623	1665.5
1942	952.5	25	198	462	685	864
1943	1303.0	..	..	..	263	167.5
1944	1229.4	19121	13089	2099	34309	22141.5
1945	1432.6	8569	6255	560	15384	10378.5
1946	1196.3	11415	10629	1323	23367	17595.5
1947	1310.6	4908	4070	742	9720	6670.5
1948	1437.6	9819	6483	732	17034	9937.5
1949	1846.6	9996	8623	1619	20238	15369.5
1950	1071.9	5541	4681	765	10987	8082.5
1951	696.0	134	202	396	732	667.0
1952	975.4	8968	9058	2449	20475	18905.2
1953	1127.8	44814	44708	8174	97696	88317.5
1954	1191.3	26426	45770	10996	83192	89331.0

In the year 1931 large number of sal trees had died in the hill and plains of Saharanpur Division. Periodic acuteness of drought had also been recorded in the years 1938, 1941, 1942 and 1943. In the years 1938 and 1941 mainly young seedlings in taungyas were damaged, while in the years 1942 and 1943 a large number of sal, *Dalbergia sissoo*, *Terminalia tomentosa* and other trees have died in Dholkhand, Lakarkot, Ganjarban and Rasulpur blocks.

In North Kheri thousands of trees died in 1931-32 necessitating special fellings. In 1942 large numbers of young sal trees were killed outright by drought and Sarota compartment 4 suffered the most. The extent of drought damage in recent years is seen from the drought fellings in the year 1953-54 (Table IV).

There have been recurring waves of drought in Horai, Kotharra and Mailani blocks of Haldwani Division. The exceptionally dry and

TABLE IV

*Drought fellings in North Kheri Division during 1953-54*

Area	Number of trees by diameter class in cm.				
	30-41	41-51	51-61	61-71	Over 71
3651 (Hectares)	.. 6705	3824	1773	305	27

hot season of 1913 and 1932 accelerated mortality in the periods 1913-17 and 1932-35. During the period 1927-36 no less than 14487 cu.m. of sawn sal timber were exported from Horai alone and a certain portion of these were from dry and wind-broken trees. The mortality of sal has been so extensive in Horai and Mailani blocks that a large area has retrogressed into a dry miscellaneous forest. Sal is not reproducing naturally.

After the severe drought of 1930-31 and 1931-32 a large number of trees died in parts of the Jaspur, Kotah and Dhauri ranges of Ram Nagar Division and a still larger number was damaged beyond recovery. This necessitated special fellings in 1932 to 1934 and 1942 to 1946. In Jaspur range where the frequency of drought waves is greatest there was a continuous loss through drought mortality over hundreds of acres from 1943 to 1947 and fellings had to be concentrated on only dead and dying trees.

Since 1907-08 two more severe droughts have occurred in Pilibhit Division in the years 1931 and 1942. In 1931 it occurred over the western part of the division, the damage being greatest in Mahof compartments 114 to 116 in which about 50% of the crop over large areas was affected. The drought of 1942 was still more severe and affected almost half of the division, the damage being greatest in Surai, Mala, Mahof and Barahi blocks in which 40-60 per cent. of the crop was affected. Severe drought in 1914 affected the Terai and Bhabar forests right through the division notably the regeneration of sal in Bhabar areas.

There have been two serious droughts in the years 1931 and 1941 in South Kheri and the damage due to 1941 drought seems to be as serious as that of 1907-08. Agarwala (1953) analysed the figures of trees removed in South Kheri as dry and semi-dry during the period 1931-49 in a recent working plan of this division from which the following details have been taken. The drought casualties have been mentioned of two kinds.

1. Those due to recurrent drought, not affected much by the annual rainfall; and
2. Those due to drought of 1941.



The number of sal trees that have been removed as dry and semi-dry in South Kheri Division (30,780 hectares of high sal forest) during the period 1931-39 and 1941-49 is given in Table V.

TABLE V  
*Number of sal trees by diameter class in cm.  
removed as dry and semi-dry*

Period	30-41	41-51	51-61	61 and over
1931-39 .. ..	20,904	7,824	2,830	2,523
1941-49 .. ..	2,34,694	93,691	24,123	8,743

For a comparison, the number of sal trees enumerated in 1939 in this division over an area of 27,406 hectares of high sal forest is also given in Table VI.

TABLE VI  
*Trees enumerated in 1939 by diameter class*

Species	in cm.			
	30-41	41-51	51-61	61 and over
Sal .. ..	1,059,772	4,98,753	1,49,518	61,760

*N.B.*—These figures exclude a high sal area of 3,375 hectares of the sal taungya working circle over which no enumerations were done.

It would appear that the 1941 drought caused a mortality of about 22% among sal tree in 30-41 cm. diameter class, 19% in 41-51 cm. diameter class and 16% in 51cm. and over class.

A drought map of the South Kheri Division had also been prepared for the period 1931-49 and this differentiates the drought affected areas into 3 main types.

	Hectares
A. Those which suffered from recurrent drought but were not affected much by the drought of 1941 ..	3,203
B. Those which were affected by the drought of 1941 ..	19,516
C. Those which were not appreciably affected either by recurrent drought or drought of 1941 ..	8,061
TOTAL ..	30,780

There are certain areas, about 1,420 hectares, included in B above which are affected both by recurrent drought and drought of 1941 and all the above figures refer to areas under high sal forest.

Areas under A and B have been further classified according to the intensity of drought as below:—

	Area affected (in hectares)
<b>A. Areas of recurrent drought—</b>	
A 1 light .. .. .	1,034
A 11 Moderate .. .. .	2,169
<b>TOTAL ..</b>	<b>3,203</b>
<b>B. Areas affected by periodic drought of 1941–42 but not affected by recurrent drought—</b>	
B 1 Light .. .. .	7,115
B 11 Moderate .. .. .	5,142
B 111 Heavy .. .. .	5,814
<b>TOTAL ..</b>	<b>18,071</b>

Areas of recurrent drought are generally along the high bank of the Sardar river and along the Kathna river and Baraunha nadi. In these areas trees have died singly or in scattered small groups. A probable cause of drought in these compartments is attributed to decreased water supplies in the adjoining rivers in recent years, due to the diversion of a major part of water of the Sardar river into the Sardar canal in the winter, and the consequent seepage from the forest areas to the river-bed. These areas generally contain a sal crop, mature or middle aged often remarkably deficient in young growth and regeneration.

Areas affected by the 1941 drought are generally in the middle alluvium, *i.e.*, east of the Chaltua-Marha line. These have been affected moderately to heavily. In the severely affected patches, sal has almost been eliminated and the crop reduced to scattered miscellaneous species with occasional sal and generally dense grasses. To the west of this line, *i.e.*, on the high alluvium the effect of 1941 drought has been absent or light and generally confined to small patches in a few places. Areas which suffered both from the recurrent drought and drought of 1941 are on the eastern edge of the middle alluvium, bordering the low alluvium.

The effects of various drought waves continue for several years and are accentuated by the insulating and sterilising effects of frequent fires. Departmental burning is carried out in these areas to induce

*de novo* sal regeneration while it has been reported that at some places fire-protective measures have also not been very successful for several years. While bad fires accentuate the process of drying up, successful fire protection helps in the process of recovery. In some of the areas where fire protection has been given and closed up satisfactorily most of the trees which had been only partially affected survived, with the result that it is now difficult to locate the damage at some places.

In some of the areas the mortality of sal had been so extensive that a large area has retrogressed into a dry miscellaneous forest and the regeneration of sal is practically at a standstill. In Haldwani attempts at clear felling and raising sal plantation artificially have not been successful. It is, therefore, very necessary that some experiments be laid down to solve this problem of natural regeneration in such dry areas. At some places some success has been achieved by sowing *Acacia catechu*, *Dalbergia sissoo*, *Bombax malabaricum*, *Kydia calycina*, etc., but it is definitely a matter for serious consideration how far it is advisable to fell sal forest and replace it by miscellaneous species.

Drought is a calamity where man becomes helpless against the forces of nature. It is very difficult to suggest any practical measures which would effectively counteract similar damage in future. Efforts can only be made towards lessening the extent of damage in the event of a similar catastrophe in future. Nature helps the forests in some areas to recover rapidly from its bad effects, especially if the drought year is followed by a good rainfall. Nature's efforts in recouping the damage combined by man's efforts can produce far-reaching results. Man's efforts in this case lie primarily in practising successful fire protection and controlled grazing.

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#### REFERENCES

- AGARWALA, V. P. 1953. *Working Plan for the South Kheri Forest Division, Uttar Pradesh 1950-51 to 1959-60*. Pp. 23-28. Lucknow.
- PANDE, D. C. 1956. Mortality in sal forests of Uttar Pradesh with reference to the recent mortality in Bahraich Division. *Proc. 9th Silv. Conf. Dehra Dun*. (Under publication).
- PRASAD, J. 1943. Drought in relation to Forestry. *Indian For.* 69: 356-60.
- RAMDAS, L. A. 1949. Rainfall in India: A brief review. *Indian J. agric. Sci.* 19: 1-19.
- SETH, S. K. 1954. *Report of the Sal Drought Committee, U.P.* Pp. 1-20.
- SINHA, R. L. 1957. Mortality of 'Sal' in Gorakhpur Forest Division, Uttar Pradesh. *Indian For.* 83: 47-53.
- TROUP, R. S. 1913. A note on the causes and effects of the drought of 1907 and 1908 on the sal forests of the U.P. *For. Bull., Dehra Dun* 22: 1-17.

# FACTORS IN THE DISTRIBUTION OF SAL (*SHOREA ROBUSTA*) FORESTS IN INDIA WITH SPECIAL REFERENCE TO U.P. AND M.P.

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It is now generally accepted that the differentiation in earth's vegetation is controlled mainly by temperature, rainfall and soil. Therefore, the study of these three factors is essential for understanding the variations encountered and the interrelationships of the forms. Changes in soil produce changes in the plant communities from place to place, in areas where the climate remains unchanged. Climate is responsible for the wide differences in the forest flora, and temperature is the most obvious factor of climate. The tropical evergreen forest flora of the west coast of India where there is high humidity, equable temperature and longer sunshine, is conditioned by rainfall. Climate, however, is not always responsible for marked differences in plant communities; in many cases edaphic factors predominate in determining the composition and extent of plant communities as is the case with a sharp line of division between sal (*Shorea robusta*) and teak (*Tectona grandis*) forests of Indian peninsula.

The main sal region in India is separated by Ganges valley. The eastern limit of sal forests is in Darrang District (Assam) and in Tripura (93° E. latitude). From this place there is a continuous strip along the sub-Himalayan tract through north Bengal, south Nepal and the north of Uttar Pradesh and it enters the Kangra District as a small outlier of stunted trees. This is the northern distribution of the species. The southern sal sub-region starts from the western portion of Bengal in the Monghyr District, from where it continues farther in Chota Nagpur, Mirzapur and then into Surguja, Jaspur and Rewa to Bilaspur, Mandla and Balghat Districts of Madhya Pradesh. It extends in the west as an outlier as far as Chindwara and Hoshangabad. The southernmost extent passes through Orissa and Raipur District into Ganjam, Koraput, Vizagapatam and Bastar where it ends.

The distribution of sal can conveniently be divided into two broad classes, viz., (i) Geographical, and (ii) Local distribution.

*Geographical distribution.*—Sal occurs in an extensive region under a wide range of prevailing climatic conditions. The amount and intensity of rainfall are of much importance in the distribution of sal. Schimper



gave primary importance to moisture conditions and viewed soil variation as secondary to temperature and moisture. Mayer, on the other hand, attached greater importance to mean temperature during the growing season. Khan (1953) is of the opinion that in M.P. the general distribution of sal is governed mainly by climate, and rainfall is by far the most potent factor. According to him in M.P., sal generally occurs in areas where total annual rainfall is well over 1,375 mm. In the entire sal-bearing zone of M.P., total annual rainfall coupled with the local geology influences the quality of sal. Total rainfall and its distribution during hot weather (March to May) is a limiting factor.

In Assam, NEFA and north Bengal sal thrives in a moist but equable climate, where the normal rainfall may be as high as 4,572 mm. The sal zone of India is, therefore, coterminous with the rainfall limits ranging from 452 mm. to 1,016 mm. In the Punjab the conditions are too dry for its existence and thus it is its westernmost limit. In the Kangra valley the rainfall varies from 1,270 mm. to 2,540 mm. which is considerably higher than in the submontane tract outside and this probably accounts for the existence of a small area of sal as an outlier in that locality. In the east, in Assam, the range of sal is limited mainly by the humidity which induces rank growth of evergreen shrubby layer and dense ground vegetation which in turn inhibits the natural regeneration of sal. In the central part of India climate conditions have partly defined the limit of sal. Champion (1933) has given a workable classification of sal types based primarily on rainfall though other factors are also taken into consideration. He has divided sal forests into four types, viz.:

(A) Dry sal (Rainfall rarely over 1,500 mm. and often under 1250 mm. mean daily relative humidity for the year under 60).

(B) Moist sal (Rainfall between 1,375 and 1,875 mm. may be between 1,250 and 2,500 mm., and mean daily relative humidity for the year between 60 and 70).

(C) Costal sal (Rainfall between 1,375 and 1,875 mm. mean daily relative humidity for the year over 70).

(D) Wet sal (Rainfall over 1,875 mm. may be between 1,500 and 5,000 m.m. and mean daily relative humidity for the year 60-70).

In the State of Uttar Pradesh these dry and moist sal forests may be regarded as variants of a climatically conditioned sal community. There is a transitional zone which is flanked on one side by moist sal association and on the other side either by dry mixed deciduous forest without sal, or a very dry sal forest of xerophytic nature. This xerophytic stage of dry sal type is mainly dominated by tree species like *Anogeissus latifolia*, *Acacia catechu*, and *Aegle marmelos*.

Though rainfall can limit the distribution of sal to a certain extent, it generally induces better growth of sal trees and thus produces better quality.

*Temperature.*—As regards temperature, the whole tract may be considered sub-tropical with hot summer, a long growing period and mild but definite winter. In the western Himalayas sal ascends in places where there is occasional snowfall and where the maximum shade temperature is not much above 32° C. It suffers considerably from severe frost, particularly in the valleys of western sub-Himalayan tract as well as in Central India. This factor often limits distribution of sal. But in parts of Chota Nagpur and M.P. it grows in localities where the temperature may rise to 46° C. or more. In the eastern part of its northern region the maximum temperature is not usually above 38° C. On the whole the maximum shade temperature varies from 34° C. at high elevation to about 47° C. in the hottest part of Chota Nagpur and the absolute minimum varies from under 0° C. to about 7° C. The range of absolute temperature also becomes a limiting factor in certain localities but in M.P. where the range of temperature is not appreciably wide, temperature does not seem to influence the distribution of sal.

*Local distribution.*—Within general climatic types distribution of sal is mainly governed by conditions of topography, geology and soil. Sal forests occur both in hilly country and on flat ground. In the hilly country sal is found to be in stunted form on the ridges. In the dry hot localities it avoids ridges altogether, and is confined to moist and cooler aspects and depressions. It grows best on the lower slopes and in the valleys where the soil is deep moist and fertile. On flat ground it is usually found in better condition near streams and in moist situations. Generally the sal forests in such areas are of better quality. In outer Himalayan valleys, sal ascends the outer hills to 1,219·2 meters and occasionally to 1,524 meters.

*Topography.*—The configuration of the ground presents considerable variety. The Siwaliks are characterised by extremely rugged and broken ground with many steep and precipitous as also gentle and level slopes. According to topography the sal forests can be classified broadly as follows (Troup, 1921):

- (i) Forests of hills and narrow valleys.
- (ii) Forests of the river terraces.
- (iii) Forests of Duns ("Duns" are broad valleys in the outer Himalayan ranges).
- (iv) Forests of the sub-montane and Bhabar tracts ("Bhabar tracts" are the deep screen deposits at the Himalayan foot-hills), and
- (v) Forests of Tarai ("Tarai" is the swampy area at the outer region of the Bhabar tract) and plains.

The extent to which the precipitation is made available to the forests depends partly on the topography of the ground. Topography is influential in promoting rapid drainage in all hilly areas, and in determining local accumulation in badly drained, low-lying localities and in

such special tracts as Tarai. Topography affects mainly gravitational water in the soil. Soil moisture is controlled by topography, aspect and physical and chemical properties of soil itself. At places where rainfall is just sufficient for the optimum growth of sal, exposure plays an important role in the distribution of sal. It affects the hygroscopic water of the soil. In M.P. southern and eastern aspects are hot and the soil on these aspects are consequently drier. On these soils sal is either absent or only poorly grown. Usually the northern and north-western aspects carry best sal. The soils on steep slopes are thoroughly drained off and have comparatively a low percentage of soil water, whereas, in depressions, gravitational water tends to accumulate on moderate slopes; and on undulating countryside soil moisture is just sufficient with adequate drainage. Thus sal is confined to low undulating hills, lower reaches of steep hill slopes, and very frequently flat stretches of land where drainage is good. In the pockets on steep slopes, where water gets a chance for accumulation, sal occurs only as a sporadic constituent of the crop.

*Geology.*—Though the general distribution of sal is governed mainly by climate its local distribution is governed largely by conditions of geology and soil. Many workers in the past tried to correlate local geology with the distribution of sal. Most of the work has been done with respect to M.P. and U.P. Middlemiss as early as 1890 pointed out that in the outer Himalayas, the distribution of sal is the limit of the tertiary zone. Smythies (1919) related plants with geology in Nainital District, and stated that geology of the tract is a predominant factor in the distribution of forest types. Champion (1933) believed that the underlying rock is of small importance, specially when the distribution of sal is correlated with the depth, aeration and moisture retaining properties of the soil. His conclusions clearly indicate that geological formation is of secondary importance. The faint correlations between the occurrence of various formations and types of sal forests, occurring in M.P., are as follows:

The best sal occurs on deep loam soils covering or derived from crystalline rocks. Good quality sal occurs on crystalline rocks which have produced only moderately deep, yellow soils. The moderate quality sal occurs on crystalline rocks producing yellow loamy soil. The poor quality sal occurs on alluvium, often turning into black soil. The low quality sal occurs on lateritic trap and crystalline rocks producing only dry shallow soils. Mooney (1947) has stated in his work on sal of M.P. that sal occurs primarily on acidic rocks and if by erosion the acidic top soil is washed away leaving behind the basic rock stratum, sal gradually disappears from the locality.

Puri (1950) tried to correlate geology with the occurrence of sal in the Siwalik hills which are composed of alternating strata of Siwalik clays and conglomerate. He stated that Siwalik clays which are ferruginous and indicate low pH value are best suited for sal. Sal is found to occur in low percentage in the tree canopy on the conglomerate. He has also correlated the occurrence of various plant communities with structural geology and the pH values of different soils. Hole (1941)

is of the opinion that excess of organic matter is detrimental to sal regeneration. Bhatnagar (1958) has also found out in his ecological studies on sal of U.P. that organic matter and pH are found to be low in soils where the growth of sal is good, and that sal prefers acidic soils. The following is the summary of the work done at the Forest Research Institute by the author (Bhatnagar, 1959):

TABLE I

*Correlation of Organic matter and pH value of soil with quality, and with either good or poor regeneration of sal*

Quality	Regeneration of sal	pH	Organic matter %	Site of collection of soil samples
I	Good	5.58	1.79	North Kheri, Sarauta 7
I	Poor	6.00	2.29	Haldwani, Lakhmanmandi 4
II	Good	5.85	1.93	South Kheri, Mailani 43
II	Poor	5.99	1.99	North Kheri, Bhadraul 4
III	Good	5.85	1.84	Dehra Dun, Asarori 10
III	Poor	6.00	2.11	South Kheri, Mailani 28
IV	Good	6.20	2.13	Bahraich, Motipur 34
IV	Poor	6.20	2.33	Bahraich, Motipur 69

Sathe (1951) is of the opinion that in M.P. better quality of sal forests with higher percentage in tree canopy is found on soft and light rocks, e.g., sand rocks, soft sandstone, micaceous schists with clay and sand. The good quality of sal in these forests occurs on acidic soils. Based on a detailed study in south Raipur, Khan (1953 a) stated that no particular rock mineral or minerals are closely associated with the occurrence of sal. However, the rocks containing greater proportion of quartz or calcite and dolomite, usually carry no sal or only poor sal. The rocks which usually carry good sal crops are graphic granite, coarse biotite-granite, amphibole-quartz-microcline, aggregates and quartz-felspar-hornblende rock. There does not seem to be any definite correlation between the sal quality and sal-bearing rocks. The occurrence of sal advance growth and the degree of its establishment is only faintly correlated with rocks containing fair amounts of hornblende and felspar.



Puri (1951) is of the opinion that low subsoil acidity, high surface and subsoil calcium and high organic matter are indicative of the causes responsible for the poor growth and regeneration of some sal forests of M.P. Bhatnagar (1958) also reached similar conclusions in his work in U.P. sal forests. The author is of the opinion that the physical properties of the soil are mainly responsible for the poor regeneration of sal and, therefore, the physical properties such as water-holding capacity, moisture per cent., and moisture equivalent may be the limiting factors for the local distribution of sal. These values are higher in the soils of good sal regions. For U.P. sal forests (Seth and Bhatnagar, 1959) these properties may be summarised thus:

TABLE II  
*Correlation of physical properties of soil with quality  
and regeneration of sal*

Quality	Re- genera- tion	Moisture con- tent	Moisture equi- valent	Water- holding capacity	Site of collection
I	Good	18.08	34.15	39.59	North Kheri, Sarauta 7
I	Poor	14.02	23.95	30.47	Haldwani Lakh- manmandi 4
II	Good	16.75	29.59	30.47	South Kheri, Mailani 43
II	Poor	15.30	28.60	35.85	North Kheri, Bhadraula 4
III	Good	16.96	30.10	36.43	Dehra Dun, Asarori 10
III	Poor	14.69	27.29	34.33	Ramnagar, Jaspur 43
IV	Good	14.93	27.30	35.50	Bahraich, Motipur 34
IV	Poor	14.77	27.43	33.11	Bahraich, Motipur 69

Champion (1933) is also of the same opinion that deep soils hold greater amount of soil water than the thin ones and in the case of truncated

soils the exposed subsoil has a much less water-holding capacity. Therefore, the distribution and quality of sal is directly correlated with soil moisture. Khan (1953 *b*) stated that texture of the soil affects the distribution of sal in M.P. Soil texture is thus associated with soil moisture and it may therefore be concluded that the distribution of sal in natural sal region is correlated directly and primarily with soil moisture whereas geology comes into play only as a secondary factor.

Hewetson (1953) considered that the chemical potential is of primary importance in the distribution of sal. He believed that certain minerals may either preponderate or inhibit the growth of sal. Bhatnagar (1958) has shown that U.P. sal forest soils are not deficient in the mineral content with regard to nitrogen, potassium and phosphorus. The results of the soil and sand culture experiments on sal at the Forest Research Institute, Dehra Dun, have shown that the minimum threshold value for potassium is somewhere near 0.08%, for nitrogen is about 0.09% and for phosphorus is about 0.05%.

*Biotic factors.*—Biotic factors also play an important role in the development and succession of sal forest. Most important of them are fire and grazing. Adverse effects of fire are many and the most obvious one is the total destruction of forest litter and humus. Usually the burnt over areas abound in grass and very often a secondary retrogression sets in, which causes abundance of grasses like *Erianthus munja*, *Imperata cylindrica* and shrubs like *Clerodendrum infortunatum*, *Mallotus philippinensis* to the very detriment and inhibition of sal regeneration. Uncontrolled or excessive grazing has very adverse effects on the regeneration of sal. Trampling and browsing of regeneration are common and the soil is hardened in which establishment of young seedlings is difficult. Erosion is accentuated and thorny unpalatable shrubs like *Carissa opaca*, *Zizyphus* spp., etc., increase in proportion. Excessive grazing and fires also arrest seral development of vegetation and sometimes lead to retrogression. In U.P. the dry sal forests are mainly confined to dry Siwalik or alluvial soils, where they are increasingly subjected to biotic influence. In this retrogressed stage sal fails to regenerate but the community is stable so long the causative factors remain operative.

Hewetson (1953) has to some extent dealt with the effects of different plant associations on soil. Under equable climatic conditions a deciduous forest cover stimulates leaching and accelerates soil development. Puri (1950) in his studies of forest communities in the forests of Dehra Dun valley has stated that under pure or almost pure canopy of mature sal forming *Sal-Syzygium* community there is ample amount of regeneration of sal, most of the soil in surface layer being acidic with pH varying from 6.0 to 6.5. In mixed stand with scattered trees of sal forming *Sal-Ougeinia* community, there is always higher pH usually above 6.5. Griffith and Gupta (1948) have ascertained that soil towards acidic side is better for the development of sal. I have found (Bhatnagar, 1958) in my studies on forest communities in sal forests of U.P. that in *Sal-Terminalia-Moghania* and *Sal-Syzygium-Randia-Ageratum* communities the regeneration of sal is good and the development is better with

higher proportion of sal in top storey from 20% to 96%. In *Sal-Anogeissus-Colebrookia* community the regeneration is poor as also the development is comparatively poor; the composition of sal in top storey is also low from 65% to 70%. In *Sal-Terminalia-Glycosmis* and *Sal-Lagerstroemia-Pogostemon* communities regeneration and development of sal are fair; they are poor and sporadic in *Sal-Ougeinia-Carissa-Sida*, while in *Sal-Ougeinia-Colebrookia* the conditions are mostly poor.

#### SUMMARY

Sal (*Shorea robusta*) occurs over extensive areas experiencing a wide range of climatic conditions. The rainfall is by far the most potent factor and the distribution pattern of rainfall is closely related to the distribution of sal forests. Roughly, sal occurs in the zone receiving annual precipitation of 1250–4575 mm. In drier localities of Madhya Pradesh, Andhra Pradesh and western U.P. soil moisture during the drought months becomes the limiting factor. At the moisture extremity in Assam it merges with evergreen formation. As regards temperature the whole tract may be considered as sub-tropical with hot summer, a long growing period and mild but definite winter. On the whole the maximum shade temperature varies from 34° C. at high elevation to about 117° F. in the hottest part in plains in Chota Nagpur and the absolute minimum varies from under 0° C. to about 7° C.

Within the general climatic types distribution of sal is mainly governed by conditions of topography, geology and soil. Topography plays an eminent role in influencing the soil moisture. Geology of the locality affects the process of soil genesis by imparting it a specific chemical aspect and a characteristic texture. Usually, soils with low pH and low organic matter contents are best suited for sal. Effects of altitude and aspect have a marked imprint in the local distribution of sal. In the drier part of sal zone, eastern and southern aspects are usually devoid of sal. Excessive desiccation on these aspects is the limiting factor. Biotic influences like excessive fire and grazing cause severity in ecological conditions and very often the seral development of vegetation is either unduly arrested or retrogressed. Also the effects of plant communities themselves on soil and general environmental factors precisely determine the distribution of *Shorea robusta* forests, to Dr. S. G. Puri for help in various ways.

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#### REFERENCES

- BHATNAGAR, H. P. 1960. Succession in some sal forests of U.P. *J. Indian bot. Soc.* 39: 22–26.
- . 1958. Ecologico-physiological studies on sal forests of U.P. *Ph.D. thesis*, Agra University, 1–307.

- CHAMPION, H. G. 1933: Regeneration and management of sal (*Shorea robusta*). *Indian For. Rec.* **19**: 1-155.
- . 1936. A preliminary survey of forest types of India and Burma. *Ibid.* N.S. *Silvic.* **1**: 1-285.
- GRIFFITH, A. L. AND GUPTA, R. S. 1948. The determination of the characteristic of soil suitable for sal (*Shorea robusta*). *For. Bull. Dehra Dun* **138**: 1-27.
- HEWETSON, C. E. 1953. A discussion on the ecological position of sal (*Shorea robusta*) in Central India. *Indian For.* **79**: 310-20.
- HOLE, R. S. 1941. Oecology of sal (*Shorea robusta*). I-III. *Indian For. Rec.* **5**: 9-102.
- KHAN, M. A. W. 1953 a. South Raipur sal forest and its ecological study with special reference to its management. *Indian For.* **79**: 184-91.
- . 1953 b. Effects of geological formation on the distribution of sal (*Shorea robusta*) in Madhya Pradesh forests. *Ibid.* **79**: 463-74.
- MIDDLEMISS, C. S. 1890. Physical geology of sub-Himalayas of Garhwal and Kumaon. *Mem. Geol. Surv. India* **24**: 1-129.
- MOONEY, H. F. 1947. A note on southern limit of sal (*Shorea robusta*) in Orissa and Bastar States. *Indian Ecol.* **2**: 27-31.
- PURI, G. S. 1950. Soil pH and forest communities in sal forests of Dehra Dun. *Indian For.* **76**: 292-309.
- AND SHARMA, B. K. 1951. The ecology of some sal forests of M.P. *Proc. 8th Silvic. Conf. Dehra Dun*, 290-94.
- SATHE, P. G. 1951. The role of geology in the distribution of sal and other plant communities in forests of Madhya Pradesh. *Ibid.* 285-90.
- SETH, S. K. AND BHATNAGAR, H. P. 1959. Characteristic of the soil suitable for sal natural regeneration. *Indian For.* **85**: 631-40.
- SMYTHIES, E. A. 1919. Geology and forest distribution. *Ibid.* **45**: 239-43.
- TROUP, R. S. 1921. *The Silviculture of Indian Trees.* **1**: 55-134 Oxford Univ. Press.



# EFFECT OF TRANSPLANTING ON WHEAT

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AMONG cereals wheat ranks as important as rice but unlike the latter, it is never subjected to transplanting in the field. Custom of transplanting the tender seedlings in many vegetables like chillies, onion, tomatoes and brinjal, etc., is quite common and everywhere the process has contributed in providing higher yields. Even second transplanting in case of chillies as reported by Singh (1953) has given 50% higher yield over the first and third transplanted plants. In rice second transplanting in poorer soils has paid less dividends over the single planting of vigorous seedlings (Ramiah, 1937).

As regards the effect of transplanting on plant morphology, several workers in the field of ecology, like Weaver, Clements and Loomis, etc., have gone into the details of root development. Recently Appala Naidu and Sankara Rao (1958) have reported an experiment on transplanting in Ragi (*Eleusine coracana* Gaertn.) and have observed that second transplanted plants gave increased yields. They have also stated that in the transplanted plants the depth of the roots increased but the spread decreased and have also been able to find correlation between root system, tillering and yield of grain and straw.

In the present paper effect of transplanting on four varieties of wheat has been studied with particular reference to its effect on many components of yield like tillers, number of fertile flowers per spikelet, number of spikelets per ear, ear length, number of grains per ear, number of mature ears per plant, grain weight per ear and 100 grain weight. Along with these, observations on height, grain yield and straw yield have also been studied.

## MATERIAL AND METHODS

The varieties included in this investigation are: (i) R.S. 31-1, a newly evolved early maturing variety for sandy and sandy loam soils in Rajasthan, (ii) C. 591, a well-known Punjab variety well suited to the canal irrigated areas in Rajasthan, (iii) N.P. 718, an I.A.R.I. strain of medium early maturity which has been introduced in Rajasthan for its rust resistance and higher yield and (iv) Jaipur Local, a commercial unimproved type.

All the four varieties used in the experiment were subjected to the following two treatments.

(A)—Control: normal sowing of the seed was done by dibbling on 30-10-1956.

(B)—Transplanting: one month old uniform seedlings were transplanted in the beds on 30-11-1956.

Each treatment was sown in a 15'×15' plot, which accommodated fifteen rows, each at a distance of one foot and about 450 seedlings; the plant to plant distance being 6".

Individual plant observations were recorded in all the treatments. Observations which concerned the many aspects of the ear, like ear length, number of spikelets per ear, fertile flowers in the different spikelets of the ear, number of grains per ear and weight of the grain per ear were recorded by averaging the observations on maximum of ten random ears selected from each plant. Rest of the observations like height, number of mature ears per plant, grain yield per plant, straw yield per plant and 100 grain weight were recorded in the usual manner.

### RESULTS

Within about seven days transplanted seedlings were well rooted and started fresh life by putting forth fresh leaves and tillers. R.S.31-1 and Jaipur Local showed quick response to transplanting by establishing earlier than N.P. 718 and C. 591.

TABLE I

Varieties	Height in cm.			100 grain weight			
	Treatments		% increase or decrease over A	Treatments		% increase or decrease over A	
	A	B		A	B		
R.S. 31-1	..	120.5	106.7	-11.50	4.97	3.77	-21.3
C. 591	..	128.1	129.2	+ 0.85	4.35	4.06	- 7.0
N.P. 718	..	113.9	94.5	-17.05	4.21	4.06	- 3.6
Jaipur Local	..	110.3	98.5	-10.69	4.51	3.48	-29.5
S.E. of treatment difference: 4.34				0.23.			
Nonsignificant				Nonsignificant			

*Height.*—In all the varieties except C. 591 there has been a decrease in height under transplanting. Even in C. 591 the increase in height is only about one centimetre which is quite marginal. The range of decrease in the transplanted plants varies from about 10 to 17%, the highest being in N.P. 718. Statistically also the differences between the two treatments are not significant.

*100 grain weight.*—All the varieties have shown decrease in grain weight when subjected to transplanting. The loss in grain weight is highest in Jaipur Local, where there is a decrease of about 29%. In

R.S. 31-1 the decrease is only 21.3%. Varieties C. 591 and N.P. 718 have been affected the least since the decrease is only 7% and 3.6% respectively. Here also the differences between the two treatments are nonsignificant.

TABLE II

Varieties	No. of tillers per plant			No. of mature ears/plant		
	Treatments		% increase or decrease over A	Treatments		% increase or decrease over A
	A	B		A	B	
R.S. 31-1 ..	6.25	25.00	+300.00	6.00	21.40	+256.6
C. 591 ..	12.10	22.80	+88.4	10.50	21.00	+100.0
N.P. 718 ..	10.20	20.90	+104.9	9.00	20.00	+122.2
Jaipur Local ..	7.80	39.90	+441.5	6.90	39.60	+430.4

S.E. of treatment difference: 5.04

5.22

Significant at 5% level.

Significant at 5% level

*Tillers.*—Transplanting has resulted in greater inducement of tillering. Although all varieties have shown increased tillering under transplanting, the percentage increase over the control is not uniform. Varieties like Jaipur Local and R.S. 31-1 have given very high percentage increase of 441.5% and 300.0% respectively. The remaining two varieties, viz., C. 591 and N.P. 718 have given very low increase of 88.4% and 104.9% respectively.

*Mature ears.*—The increased tillering under transplanting gave way to the development of many late tillers which did not set any seed. Hence observation on mature ears per plant was also recorded. The observation of mature ears is following the same pattern as that of the tillers. Among the varieties, R.S. 31-1 produced more late tillers under transplanting. In all the varieties percentage increase in mature ears over the control is more than 100%. Jaipur Local has exhibited the highest increase of about 430%.

*Ear length.*—In all the varieties ear length finds an increase of about one cm. under transplanting. The percentage increase in ear length is highest in local, which is 15.2% and is the lowest in C. 591 where it is only 8.4%.

*Number of spikelets per ear.*—Except in N.P. 718, there is an increase in the number of spikelets per ear. N.P. 718 has shown a decrease of 5.4% over the control which comes to about one spikelet per ear. Very high percentage increase of about 28% and 26% has been obtained in varieties R.S. 31-1 and Jaipur Local respectively.

*Number of fertile flowers per spikelet.*—Observation on fertile flowers per spikelet has been taken by recording the number of seeds set in spikelets at upper, middle and lower region of the ear. Generally in all varieties under control treatment, the upper spikelets have two, the middle ones three to four and lower spikelets two fertile flowers in each spikelet. Under transplanting fertility of the upper spikelets has remained unchanged, whereas in the middle and lower spikelets the fertility has increased (Table III). In comparison to the upper and middle spikelets the increase in fertility is more pronounced in the lower spikelets of all the varieties.

TABLE III

Varieties	Ear length in cm.			No. of spikelets per year			No. of fertile flowers/spikelet	
	Treatments		% increase or decrease over A	Treatments		% increase or decrease over A	Treatments	
	A	B		A	B		A	B
R.S. 31-1 ..	8.50	9.60	12.9	16.00	20.5	28.12	U*-2	U-2
							M-(3-4)	M-5
							L-2	L-4
C. 591 ..	10.76	11.67	8.4	19.70	21.7	10.10	U-3	U-(2-3)
							M-(3-4)	M-4
							L-2	L-(3-4)
N.P. 718 ..	9.05	10.40	14.9	20.60	19.5	-5.40	U-2	U-2
							M-(3-4)	M-(3-4)
							L-2	L-(3-4)
Jaipur Local	9.50	10.95	15.2	18.10	22.8	25.90	U-2	U-2
							M-(3-4)	M-4
							L-2	L-(3-4)

S.E. of treatment difference:  
Significant at 5% level.

0.23

Nonsignificant at 5% level

1.36

\* U-Upper.  
M-Middle.  
L-Lower.

*Number of grains per ear.*—Number of grains per ear in all the varieties have increased under transplanting. The percentage increase over the control is 75.5%, 31.4%, 21.1%, and 16.6% in varieties R.S. 31-1, Jaipur Local, C. 591 and N.P. 718 respectively.



*Grain weight per ear.*—Grain weight per ear is the highest in R.S.31-1 under transplanting. In rest of the varieties percentage increase over the control is varying from 23.9% in Jaipur Local to 26.3% in C 591 and N.P. 718 (Table IV).

TABLE IV

Varieties	No. of grains per ear			Grain weight per ear in gm.		
	Treatments		% increase or decrease over A	Treatments		% increase or decrease over A
	A	B		A	B	
R.S. 31-1 ..	38.0	66.7	+75.5	1.96	3.26	+66.3
C. 591 ..	54.9	66.5	+21.1	2.54	3.21	+26.3
N.P. 718 ..	55.9	65.2	+16.6	2.39	3.02	+26.3
Jaipur Local ..	46.2	60.7	+31.4	2.09	2.59	+23.9

S.E. of treatment difference:  
Significant at 5% level.

4.36

0.179  
Significant at 5% level.

*Number of grains per plant.*—Under transplanting Jaipur Local and R.S. 31-1 have exhibited an excellent increase in the number of grains per plant, which is up to the increase of 436.5% in Jaipur Local and 428.3% in R.S. 31-1 over the control. In comparison to Jaipur Local and R.S. 31-1, varieties N.P. 718 and C. 591 have shown very poor performance under transplanting since increase over the control is only 132% and 98% respectively as shown in Table V.

TABLE V

Varieties	No. of grains per plant			Grain yield per plant in gm.			Straw yield per plant in gm.		
	Treatments		% increase or decrease over A	Treatments		% increase or decrease over A	Treatments		% increase or decrease over A
	A	B		A	B		A	B	
R.S. 31-1 ..	179.7	949.7	+428.3	8.83	46.25	+423.7	18.01	90.75	+403.8
C. 591 ..	476.6	943.7	+98.0	19.45	41.49	+113.3	38.93	94.49	+142.7
N.P. 718 ..	375.9	872.4	+132.0	15.51	37.89	+144.2	24.75	52.53	+112.2
Jaipur Local ..	265.9	1426.6	+436.5	12.02	49.97	+315.7	17.89	101.00	+464.6

S.E. of treatment difference:  
Significant at 5% level,

161.06

4.47

Significant at 1% level,

12.08

Significant at 5%

*Grain yield per plant.*—Grain yield is the most important consideration in this experiment. Differences exhibited by the treatments are also highly significant. In the normally dibbled plants the highest grain yield of 19.45 gm. per plant has been given by C. 591, whereas in the rest of the varieties the yield is varying from about 8–15 gm. per plant. On transplanting all the varieties have shown increased yields over the control treatment. The highest grain yield under transplanting has been obtained in Jaipur Local which is 49.97 gm. per plant. The lowest yielder in this respect has been N.P. 718. Now when the varietal response of transplanting is assessed over the normal sowing, it is observed that R.S. 31-1 and Jaipur Local, which have given an increase of 423.7% and 315.7% respectively (Table V), have shown an excellent performance under transplanting while the remaining two varieties N.P. 718 and C. 591 have shown an increase of only 144.2% and 113.3% respectively.

*Straw yield per plant.*—Here also all the varieties have shown increase in straw yield when transplanted. In varieties Jaipur Local, C. 591 and R.S.31-1 straw yield is 101.00 gm., 94.49 gm. and 90.73 gm. respectively under transplanting but in comparison to their respective controls, the percentage increase in straw is 464.6% in Jaipur Local, 403.8% in R.S. 31-1 and 142.7% in C. 591 (Table V).

#### DISCUSSION

There is reduction in height under transplanting conditions in all the varieties except C. 591, where also the increase is only one cm. or 0.85% over the control. In rest of the varieties the decrease varies from about 10 to 17%.

Straw yield is mainly controlled by tillering and height. Although height has decreased under transplanting, it is mainly the tillering which has contributed the most in increasing the straw yield under transplanting. The observations show correlation between the yield of the straw and the number of tillers. The same correlation has been observed by Naidu and Rao (1958) in Ragi also. The same varieties Jaipur Local and R.S. 31-1 which had given an increased tillering of about 300 to 400% have shown very high increase in straw yield on transplanting; whereas the lower increase in tillering obtained by C. 591 and N.P. 718 has resulted in giving lower increase in straw yield.

All the components of grain yield except the 100 grain weight display an increase under transplanting in all the varieties. The loss in grain weight is very high in Jaipur Local and R.S.31-1. The maximum tillering has also been obtained by Jaipur Local and R.S.31-1 which is about 300 to 400% greater than that in the normal sowing. Number of mature ears was also found to be maximum in the Jaipur Local but the percentage increase over the control was 430.4% in Jaipur Local and 256.6 in R.S. 31-1. The effect of transplanting on the length of the ear is rather

uniform in all the varieties since it shows only one centimetre increase. Total number of spikelets per ear have shown an increase under transplanting in all the varieties except N.P. 718. R.S. 31-1 and Jaipur Local have shown very high percentage increase of about 28% and 26% respectively in comparison to their controls. Fertility of the lower spikelets in all the varieties has greatly been effected under transplanting, since the number of fertile flowers has increased from two to four. In upper spikelets the fertility has remained unchanged. In the middle spikelets there is no increase in fertility in varieties N.P.718 and Jaipur Local but in varieties R.S. 31-1 and C. 591 some increase is perceptible.

Since number of grains per ear is directly effected by the ear length, spikelets per ear and fertility of the spikelets, the expected increase under transplanting in all the varieties was also observed. The percentage increase over the control is the highest in R.S. 31-1 which has shown about 75% increase. Like number of grains per ear the grain weight per ear has also increased on transplanting and the percentage increase over the control is also the highest in R.S. 31-1.

As has already been mentioned earlier that all the components of grain yield except the 100 grain weight have shown an increase under transplanting, the grain number and the grain weight per plant has also shown an increase in all the varieties. For both number of grains and the total yield per plant varieties R.S. 31-1 and Jaipur Local have given very high increase of about 300 to 400% whereas N.P. 718 and C. 591 show an increase of about 113 to 144%. Wheat is never transplanted in practice but such spectacular high yields of grain and straw obtained in varieties R.S. 31-1 and Jaipur Local, does not rule out the possibility of getting economically higher yields of these varieties under transplanting and intensive cultivation.

#### SUMMARY

Effect of transplanting was studied in four varieties of vulgare wheat, viz., R.S. 31-1, C. 591, N.P. 718 and Jaipur Local. Observations were recorded on height, tillering, mature ears per plant, ear length, spikelets per ear, fertile flowers per spikelet, grain number per ear, grain weight per ear, 100 grain weight, straw yield per plant and grain yield per plant under transplanting and normal sowing.

Except the height and 100 grain weight, all the other aspects have shown an increase under transplanting in all the varieties. Varieties R.S. 31-1 and Jaipur Local have given an excellent performance under transplanting. Increase in grain yield is about 300 to 400% and straw yield about 400 to 460% over the control.

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#### REFERENCES

- APPALA NAIDU, B. AND SANKARA RAO, K. S. R. K. 1958. Effect of transplantation on Ragi Plant. *J. Indian bot. Soc.* 37: 194-99.
- RAMIAH, K. 1937. *Rice in Madras*. Government Press, Madras.
- SINGH, T. C. N. 1953. Effect of second transplantation on earliness and yield of chilli. *Bihar agric. J.*



# A STUDY OF THE HYDROPHYTES OF BARODA AND ENVIRONS

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IN India the systematic and ecological study of the hydrophytes as a group has not received adequate attention, although such a study has always yielded very useful data on the ecology, floristic composition and various other aspects of this interesting group of plants. Mention must be made of a few notable contributions such as Biswas and Calder's (1937) book on the marsh and aquatic plants of India; Kapadia's (1950) booklet on the plant-life of Mahagujarat, wherein he lists some of the common aquatic plants of this region; Saxton and Sedgwick's (1918) Flora of North Gujarat, in which a broad ecological classification of the flora is given and a few others by Ratnam and Joshi (1952), Mirashi (1954, 1957), Navalkar (1956) and Kachroo (1956). But, as far as the authors are aware, no work is done on the floristic composition and distribution of the aquatic plants in this part of the Bombay State.

A beginning in this direction is made by the authors in the present paper. As far as the study of the hydrophytes of Baroda is concerned, the only work that has been done, deals with the seasonal variations in the vegetation and phenology of the plants occurring in and around a pond at Harni, a village  $2\frac{1}{2}$  miles N.E. of Baroda. In the present paper, it is proposed to give a comprehensive data on the distribution and floristic composition of the hydrophytes occurring in the various habitats of Baroda and its rich environs.

## AREA OF STUDY

An area of about 50 sq. miles has been selected for this particular study. The accompanying map shows the area surveyed so far.

Baroda was the capital of the former Baroda State. It is one of the important cities of the Bombay State and is 110 ft. above sea-level. The climate is more or less tropical. Highest humidity is recorded during the months of June-September. March-May are the driest months having lowest humidity. All these climatic factors have a profound influence on the vegetation in general and the aquatic flora in particular. Soil varies from black aluvial to red loam and is comparatively dry except in the rainy season,

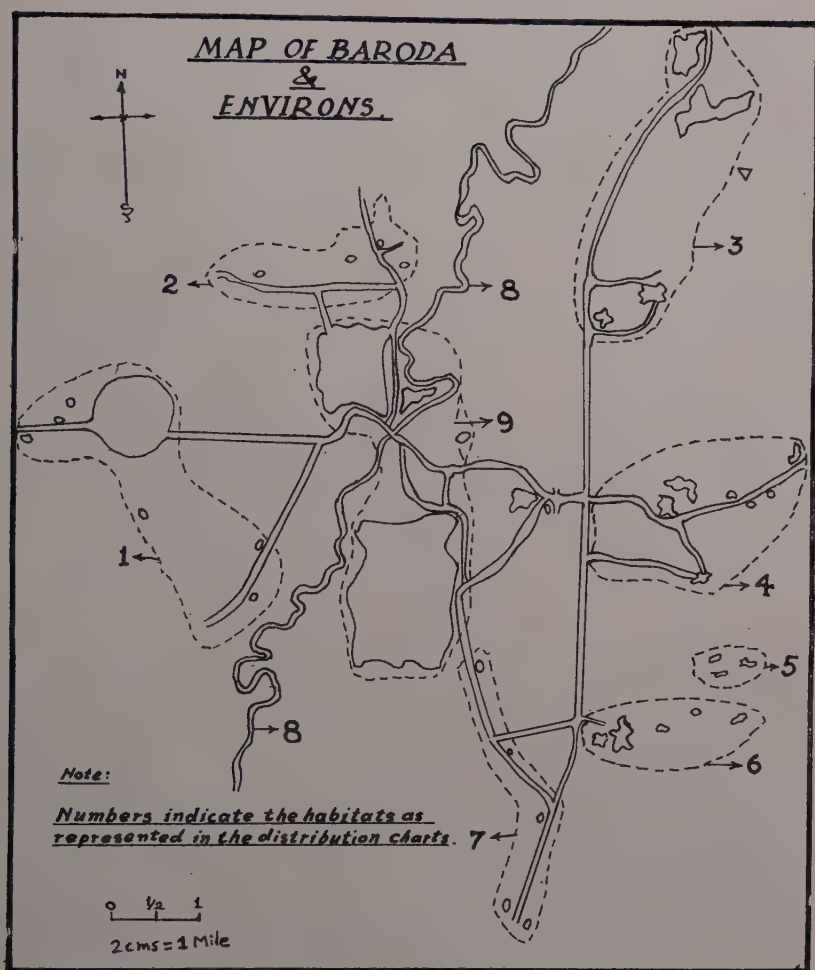
## HABITATS

Hydrophytes are the denizens of ponds, puddles and marshes and hence were studied from such localities in Baroda. There are a number of ponds, natural or artificial; a great number of puddles, which are dry in the hot months and are filled up during the monsoons; River Vishwamitri and tributaries and a number of marshes or swamps, which exhibit a wide variety of aquatic flora. For our convenience, we have divided the area of study into 9 smaller areas, each of them having a number of habitats, where hydrophytic flora can flourish. The areas are Race-course, Nizampura and Chhani, Harni, Panigate, Sewage-Disposal, Pratap-Nagar, Lalbaug and Makarpura, River Vishwamitri and tributaries and finally the City area. Each area is fairly large and as such only the most important habitats have been taken into consideration while preparing the distribution chart.

## DESCRIPTION OF THE PONDS

Race-course, Nizampura and Chhani, Lalbaug and Makarpura and the City areas are comparatively poorer in aquatic flora. Some marshes in the Race-course area show *Limnophila heterophylla*, *Sesbania bipinnata*, *Scirpus supinus*, *Caesulia axillaris* and *Ludwigia parviflora*. *Ipomoea aquatica*, *Asteracantha longifolia*, *Eclipta prostrata* are some of the dominant plants in many of the ponds or puddles in the above-mentioned areas. The marshes near the 'Nagarwada Talao' in the City area support an association of *Limnophytum obtusifolium* and *Asteracantha longifolia*. *Isoetes coromandeliana*, *Butomopsis lanceolata* and *Scirpus quinquefarius* are some of the noteworthy plants of this area.

In the Harni area are included the Harni ponds (I and II). Varoshia and Sirsia ponds and 'Vaidawadi' an outlet for the Sirsia pond. The Harni ponds are perennial, though the water-level goes down considerably during the hot months. The aquatic flora here consists of *Nymphaea stellata*, *Nelumbium speciosum*, *Neptunia oleracea*, *Lagarosiphon alternifolius* in their waters, *Limnophila indica*, *Butomopsis lanceolata*, *Isoetes coromandeliana*, *Eleocharis plantaginea* as amphibious hydrophytes near the banks and *Enicostemma verticillatum*, *Elytraria acaulis*, *Acanthospermum hispidum* on their wet slopy banks. The marshes and the rice-fields round about show the presence of *Eriocaulon* sp., *Ludwigia parviflora*, *Dopatrium junceum* and *Utricularia reticulata*. *Potamogeton crispus* and *Hydrilla verticillata* are some of the important plants found in one distant corner of the Sirsia pond. As the water-level in this pond goes up, the overflowing water is drained through a canal known as 'Vaidawadi'. This canal supports a rich hydrophytic flora of *Nymphaea stellata*, *Ipomoea aquatica*, *Pseudoraphis aspera*, *Ceratophyllum demersum* in the waters, *Eleocharis plantaginea* and *Limnophytum obtusifolium* as amphibious hydrophytes and *Cyanotis axillaris* and *Phaseolus trilobus* on the wet banks. On the advent of the dry months, *Ipomoea aquatica* dominated the water surface as well as the muddy banks, *Asteracantha longifolia* became more



aggressive occupying the area previously occupied by *Limnophyllum obtusifolium*. A considerable portion of the wet banks was exposed with the result that *Blepharis molluginifolia*, *Vernonia cinerea*, *Alysicarpus vaginalis* became firmly established. As the canal was reduced to its maximum, *Ipomoea aquatica*, *Marsilia quadrifolia*, *Gnaphalium indicum* and *Dentella repens* formed the main component of the vegetation present at that time.

Panigate area is probably the richest as far as the aquatic vegetation is concerned. Most of the temporary ponds in this area are utilised for the cultivation of water-chestnuts, though during the dry months, they show the presence of *Hydrilla verticillata*, *Azolla* sp., *Juncellus*

*pygmaeus*, *Potentilla supina* and *Gnaphalium indicum*. *Ottelia alismoides* is found in a small temporary pond in this area. Dudheshwar Mahadeo pond supports an association of *Nymphaea stellata*, *Ipomoea aquatica* on its waters and *Cyperus esculentus*, *Scirpus articulatus*, *Caesulia axillaris*, *Ludwigia parviflora* on the muddy water-logged banks, while Madhavapura pond exhibits a similar type of association on its surface-waters but differs in its fringe vegetation, which consists mainly of *Eleocharis plantaginea*-*Limnophytum obtusifolium*-*Oryza sativa* var. *fatua* community. Small ponds and puddles near 'Mohmed Talao' show the presence of *Sagittaria guyanensis*, *Ceratophyllum demersum*, etc.

The Sewage Disposal area shows a striking difference in its aquatic flora, which abounds in most of the nitrophilous species like *Asteracantha longifolia* and *Eclipta prostrata*. The marshes (whole area is saturated with sewage water throughout the year) show a dominance of *Juncellus laevigatus*, *Cyperus brevifolius*, *Cyanotis axillaris* and *Phyla nodiflora*. 'Koma' and 'Dudhiya' ponds have a vegetation very much different from that of any of the ponds in the area surveyed so far. These ponds are completely occupied on their surface-waters by the alga, *Microcystis*. Along the margins can be found plants like *Lemna polyrrhiza*, *Ceratophyllum demersum*, *Ipomoea aquatica* and *Typha* sp. Kapuria Talao supports an association of *Eleocharis plantaginea*-*Nymphaea stellata* along with *Limnanthemum cristatum* and *Scirpus maritimus*.

Pratap-Nagar area includes Danteshwar ponds, Mandir pond and a number of puddles and water canals. Danteshwar ponds lie on the S.E. of the Baroda City, near Pratap-Nagar Railway Station. The ponds show a luxuriant growth of *Utricularia stellaris*, *Nymphaea stellata*, *Hydrilla verticillata*, *Lagarosiphon alternifolius*, *Trapa bispinosa*, *Marsilea quadrifolia*, *Aeschynomene indica* in its waters and *Phyla nodiflora*, *Merremia emarginata*, *Dentella repens*, *Eclipta prostrata* on its margins and wet banks. *Trigonella occulta* forms the carpet vegetation during the dry months when the water level goes down considerably. Around the main ponds, there are number of temporary water collections which invariably show *Monochoria vaginalis* in the centre and Marsh plants like *Ludwigia parviflora*, *Caesulia axillaris*, *Murdannia nudiflora*, *Ammannia baccifera*, *A. multiflora*, *Fimbristylis miliacea* and *Cyperus difformis* along its margins. Such water collections, when dry during the hot months, show a luxuriant growth of *Heliotropium supinum*, *Chrozophora prostrata*, *Glinus lotoides* and *Polygonum plebejum*. Mandir pond supports an association of *Eleocharis plantaginea*-*Nymphaea stellata* along with *Hygrorrhiza aristata*, *Asteracantha longifolia* near the margins and *Fimbristylis junciformis* and *Juncellus pygmaeus* on its banks. The puddles in the area show a dominance of *Lemna polyrrhiza*. The water canals have *Ceratophyllum demersum* in its waters and *Eclipta prostrata* and *Cyperus bulbosus* on its banks.

The River Vishwamitri takes its origin in the Pavagadh Hills and runs through the city of Baroda. During the monsoons, the river is usually in spate and the banks are flooded with the result that no vegetation is seen during these months. After the monsoons, the water level goes down, exposing the banks throughout. In the month of



October, the banks are muddy, showing a very sparse vegetation. At this time *Xanthium strumarium*, *Crotalaria medicaginea* and *Asteracantha longifolia* are the only plants available. During the dry months, *Lemna polyrrhiza*, *Marsilea quadrifolia*, *Scirpus litoralis*, *Cyperus difformis*, *Bacopa monnieri*, *Canscora diffusa*, *Ammannia baccifera*, *Gnaphalium indicum*, *G. pulvinatum*, *Sphaeranthus indicus*, *Verbascum coromandeliana*, *Phyla nodiflora* among others were collected. A thorough exploration of the banks is utterly necessary to throw some light on the problem of seasonal variations in the vegetation.

In the artificial ponds in the University area *Pistia stratiotes*, *Cyperus alternifolius*, *Equisetum debile* are some of the hydrophytes grown for ornamental or study purposes.

#### DISCUSSION

The aquatic and sub-aquatic communities of the ponds and puddles investigated so far include the following:—

##### A. Free-floating communities—

I. Plankton—abundantly found in steady or very slowly flowing water; *ex.*, *Hydrodictyon* (Vishwamitri waters), *Tetraspora* (Vaidawadi), *Zygnema* (Harni pond), etc.

II. Spermatophyta—Occur in still waters of the puddles; *ex.*, *Utricularia*, *Lemna*, etc.

##### B. Communities of rooted plants entirely submerged—

Found in fairly deep waters on the substrata of soft mud. *ex.*, *Chara*, *Nitella*, *Lagarosiphon*, etc.

##### C. Communities of rooted and submerged plants with floating leaves—

Found in clear waters in the sheltered regions of the puddles and ponds, *ex.*, *Nymphaea*, *Limnanthemum*, *Trapa*, etc.

##### D. Marsh communities—

Marsh plants tend to occur with their roots in water-logged soils. These plants are very common and occupy large areas. *ex.*, *Limnophytum*, *Scirpus*, *Aeschynomene*, etc.

Most of the ponds are flooded during the monsoons and show the presence of some of the aquatic communities mentioned above, on its surface or near the banks. The water level subsequently goes down, exposing the wet banks which invariably show a luxuriant growth of a carpet vegetation of herbaceous plants such as *Acanthospermum hispidum*, *Alysicarpus vaginalis*, *Bacopa monnieri*, *Bergia odorata*, *Blepharis molluginifolia*, *Cyanotis axillaris*, *Dentella repens*, *Elytraria acaulis*, *Enicostemma verticillatum*, *Gnaphalium indicum*, *G. pulvinatum*,

*Distribution of Hydrophytes in the various habitats of Baroda and environs.*

No.	Name of the Plant	1	2	3	4	5	6	7	8	9
1	<i>Nymphaea stellata</i> Willd. ..	..	—	—	×	×	×	×	—	—
2	<i>Nelumbium</i> <i>speciosum</i> Willd. ..	..	—	—	*	×	—	—	—	—
3	<i>Melochia corchorifolia</i> L. ..	×	×	×	×	—	×	×	—	×
4	<i>Corchorus capsularis</i> Linn. ..	..	×	—	—	×	—	—	—	—
5	<i>Sesbania bipinnata</i> Fawc. et Rendl. ..	..	×	—	×	×	—	—	—	—
6	<i>Aeschynomene indica</i> L. ..	×	×	×	*	—	×	—	—	×
7	<i>Neptunia oleracea</i> Lour. ..	—	—	×	—	—	×	—	—	—
8	<i>Ammannia multiflora</i> Roxb. ..	..	—	—	×	×	—	×	—	—
9	<i>Ammannia baccifera</i> L. ..	×	×	×	*	×	×	×	×	×
10	<i>Ludwigia parviflora</i> Roxb. ..	×	—	×	×	×	×	×	—	—
11	<i>Trapa bispinosa</i> Roxb. ..	—	—	×	*	—	×	×	—	—
12	<i>Eclipta prostrata</i> Linn. Mantiss. ..	..	×	×	×	×	*	×	×	×
13	<i>Caesulia axillaris</i> Roxb. ..	×	×	×	×	×	×	×	×	×
14	<i>Limnanthemum indicum</i> Thw. ..	..	—	—	×	×	—	×	—	—
15	<i>L. cristatum</i> Griesb. ..	..	—	—	*	*	×	×	—	—
16	<i>Ipomoea aquatica</i> Forsk. ..	×	*	×	*	×	×	×	×	×
17	<i>Limnophila indica</i> Linn. Druce. ..	..	—	—	×	×	—	—	—	—
18	<i>L. heterophylla</i> Benth. ..	×	—	×	×	—	×	—	—	—
19	<i>Dopatrium junceum</i> Ham. ..	—	—	×	×	—	×	—	—	—

No.	Name of the Plant	1	2	3	4	5	6	7	8	9
20	<i>Utricularia stellaris</i> L. ..	—	—	×	×	—	×	—	—	—
21	<i>U. reticulata</i> Smith. ..	—	—	×	×	—	—	—	—	—
22	<i>Asteracantha longifolia</i> Nees. ..	×	×	×	*	*	*	×	×	×
23	<i>Hygrophila serpyllum</i> T. Anders. ..	—	—	×	×	—	×	—	—	—
24	<i>Alternanthera sessilis</i> R. Br. ..	×	×	×	×	×	×	×	×	×
25	<i>Ceratophyllum demersum</i> Linn. ..	—	—	×	×	×	×	—	—	—
26	<i>Hydrilla verticillata</i> Presl. ×	×	×	×	×	—	×	×	—	×
27	<i>Lagarosiphon alterni- folius</i> Roxb. Druce ..	—	—	×	×	—	—	—	—	—
28	<i>Vallisneria spiralis</i> Linn. —	—	—	×	×	—	—	—	×	—
29	<i>Ottelia alimoides</i> Pers. ..	—	—	—	×	—	—	—	—	—
30	<i>Monochoria vaginalis</i> Presl. ..	×	—	×	×	—	×	—	—	—
31	<i>Typha</i> sp. ..	—	—	—	—	×	—	—	—	×
32	<i>Lenna polyrhiza</i> Linn. ..	×	×	×	×	×	×	—	×	×
33	<i>L. gibba</i> Linn. ..	—	—	×	×	—	—	—	—	—
34	<i>Sagittaria sagittifolia</i> Linn. ..	×	—	×	×	—	×	—	—	×
35	<i>S. guyanensis</i> H.B. & K. —	—	—	×	×	—	—	—	—	—
36	<i>Limnophytum obtusi- folium</i> (Linn.) Miq. ..	×	—	×	*	—	×	—	—	×
37	<i>Butomopsis lanceolata</i> Kunth. ..	—	—	×	×	—	×	—	—	×
38	<i>Aponogeton monostachyon</i> L. ..	—	—	×	×	—	×	—	—	—

No.	Name of the Plant	1	2	3	4	5	6	7	8	9
39	<i>Potamogeton indicum</i> Roxb. ..	..	—	—	×	×	—	—	—	—
40	<i>P. crispus</i> L. ..	..	—	—	×	—	—	—	—	—
41	<i>Eriocaulon</i> sp. ..	..	—	—	×	×	—	×	—	×
42	<i>Cyperus brevifolius</i> Hassk. ..	..	—	×	×	*	*	—	×	×
43	<i>Juncellus laevigatus</i> C.B. Cl. ..	..	—	×	×	*	*	×	×	—
44	<i>Cyperus difformis</i> Linn. ..	×	—	×	*	×	*	×	×	×
45	<i>C. esculentus</i> L. ..	..	—	—	×	×	—	×	—	×
46	<i>C. exaltatus</i> Retz. ..	..	—	—	—	×	—	×	—	×
47	<i>Eleocharis plantaginea</i> R. Br. ..	..	—	—	*	*	—	*	—	—
48	<i>Fimbristylis miliacea</i> Vahl. ..	..	—	—	×	×	—	*	—	—
49	<i>F. quinquangularis</i> Vahl. ..	—	×	×	×	—	×	—	—	×
50	<i>Scirpus articulatus</i> Linn. ..	—	×	*	*	—	×	×	—	×
51	<i>S. litoralis</i> Schrad. ..	..	—	—	*	*	—	×	×	*
52	<i>S. supinus</i> Linn. ..	..	×	—	×	×	—	—	—	×
53	<i>Hygrorrhiza aristata</i> Nees. ..	—	—	*	*	—	×	—	—	×
54	<i>Pseudoraphis aspera</i> Pilger. ..	..	—	—	×	×	—	—	—	—
55	<i>Oryza sativa</i> var. <i>fatua</i> . ..	×	×	*	*	×	×	—	—	×
56	<i>Isoetes coromandeliana</i> L. ..	—	—	×	—	—	—	—	—	×
57	<i>Marsilea quadrifolia</i> L. ..	×	×	*	*	×	—	×	×	×
58	<i>Azolla</i> sp. ..	..	—	—	×	×	×	×	—	—

1. Race—course area; 2. Nizampura and Chhani area; 3. Harni area;  
 4. Panigate area; 5. Sewage Disposal area; 6. Pratap-nagar area;  
 7. Lalbaugh and Makarpura area; 8. River Vishwamitri and tributaries. 9. City area.

—, Absent.

×, Present.

\*, Abundant.



*Heylandia latebrosa*, *Hybanthus enneaspermum*, *Juncellus pygmaeus*, *Lauraea nudicaulis*, *Potentilla supine*, etc.

During the dry months, the water level recedes to its maximum and the ponds and puddles present a characteristic plant community consisting of *Argemone mexicana*, *Alhagi camelorum*, *Chrozophora prostrata*, *Coldenia procumbens*, *Cressa cretica*, *Heliotropium supinum* and *Polygonum plebejum* on their exposed soils.

The 58 species (excluding the wetland and terrestrial species) encountered in the survey belong to 46 genera and 27 families. Families in groups, other than the angiosperms, include the Isoetaceae, Salviniaceae and Marsileaceae. Of the 24 families of angiosperms, there are 9 monocotyledonous and 15 dicotyledonous families. The percentage of the monocot and dicot families in this survey comes to 37 and 63 respectively. The monocot families contribute 30 species distributed among 23 genera, while the dicot families have 25 species dispersed through the remaining genera. Though the ratio of the number of monocot families to that of dicot families comes to 1:1.7, the ratio of the number of species belonging to those classes is 1:1.1.

The distribution of these aquatic plant communities in the various areas is certainly interesting. From the distribution chart, it may be concluded that the North-East, East and South-East areas of the region under study are considerably rich in quality and quantity as compared to the rest of the areas. These differences in the distribution can be attributed to the various conditions which are responsible for the development of macroscopic plants in water bodies. These conditions can be classified as physical, chemical and biotic. Physical factors include amplitude of water level, turbidity and sedimentation, type of bottom and depth and temperature of water. The chemical factors like oxygen tension, nutrients, acidity and alkalinity are always more important. Human and animal activities also play a significant role in the development and distribution of the higher aquatic plants. Unless a detailed ecological study of the different ponds in Baroda is made, this peculiar pattern of distribution of the aquatic communities cannot be accounted for.

#### SUMMARY

1. An introduction stressing the need of a comprehensive data on the floristic composition and distribution of the aquatic plant communities occurring in Baroda and its rich environs.

2. Description (location, climate, etc.) of the area of study is also given. The area is divided into 9 smaller areas.

3. Description of the various ponds and puddles with a brief account of the aquatic flora occurring there.

4. A distribution chart, giving in details the distribution of the aquatic plants in the various habitats of Baroda and environs. Only the most important habitats have been taken into consideration while preparing the chart.

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## REFERENCES

- ARBER, A. 1920. *Water-plants*. Cambridge.
- BISWAS, K. AND CALDER, C. C. 1936. *Handbook of Common Water and Marsh Plants of India and Burma*. Government Press, Delhi.
- COOKE, T. 1908 *Flora of the Presidency of Bombay*, I and II.
- FASSETT, N. C. 1957. *A Manual of Aquatic Plants*. Univ. Wisc. Press, Madison.
- HOOKE, J. D. 1872-97. *Flora of British India*, I-VII.
- KACHROO, P. 1956. Plant types of the ponds of the lower Damodar Valley. *J. Indian bot. Soc.* **35**: 430-43.
- KAPADIA, G. A. 1950. *Plant-life of Mahagujarat*. Guj. Res. Soc., Bombay.
- MIRASHI, M. V. 1954. Studies in the hydrophytes of Nagpur. *J. Indian bot. Soc.* **33**: 299.
- . 1957. Hydrophytes of Umred. *Ibid.* **36**: 396-407.
- NARAYANA, D. V. 1939. Aquatic weeds in the Deccan irrigation channels. *J. Ecol.* **27**: 66.
- PATNAIK, H. AND PATNAIK, N. K. 1956. The hydrophytes of Cuttack. *J. Indian bot. Soc.* **35**: 167-70.
- PENFOUND, WM. T. 1953. Plant communities of Oklohama lakes. *Ecology* **34**: 561-83.
- PHATAK, V. G. AND SATAKOPAN, SAVITHA. 1957. Plant types of the ponds of the plains around Baroda. I. Pond vegetation at Harni. *J. M.S. Univ. Baroda* **6**: 11-48.
- SAXTON, W. T. AND SEDGWICK, L. J. 1918. Plants of Northern Gujarat. *Rec. bot. Surv. India* **6**: 221-23.
- WEINTROUB, DORA. 1933. A preliminary account of the aquatic and sub-aquatic vegetation and flora of Witwatersrand. *J. Ecol.* **24**: 44.
- WELCH, P. S. 1935. *Limnology*. McGraw Hill Book Co., New York.





Prof. Shankar Purushottam Agharkar (1884-1960)



PROFESSOR SHANKAR PURUSHOTTAM  
AGHARKAR, M.A., Ph.D., F.L.S., F.N.I.  
(1884-1960)

A Biographical Note

PROFESSOR S. P. AGHARKAR was born on the 18th November 1884 (*Margashirsha Pratipada, Shaka* 1806) in a family of Chitpawan Brahmins called Datar, hailing from village Kothare in the Ratnagiri District, Maharashtra State. Professor Agharkar's early education was through Marathi, Kannada and English at various places. He matriculated in 1902 from the Government High School, Dharwar, and took his B.A. degree in 1906, obtaining a first class. At his B.A. examination he won the Bell prize for his proficiency in English and he was awarded the Lisboa scholarship for practical Botany at the Grant Medical College, Bombay, in 1907. He took his M.A. degree in 1908 with Botany, Zoology and Geology as his subjects. Later, he served as Lecturer and Head of the Biology Department in the Elphinstone College, Bombay, from 1910-13. During this period, he discovered a new freshwater medusa in the Koyna valley which was described as *Limnocnida indica* Annandale.\* With Dr. Annandale he toured the whole of the Western Ghats, and collected several new animals and plants of which the freshwater sponges turned out to be very interesting. Through Dr. Annandale he came under the influence of Dr. F. H. Graveley and Sir William Wright Smith of the Royal Botanical Garden, Sibpur, Calcutta. In 1913 he was appointed honorary correspondent of the Indian Museum, Calcutta, and attended the Centenary Celebrations of the Indian Museum. While at the Indian Museum he described adult and larval forms of the net-veined midges (Blepharoceridae) from Kashmir, including *Philoris bionis* Agharkar, and, for the first time, the larval forms of three other species till then known only from South Africa. In token of his regard for him, Dr. Graveley named a new centipede from the Western Ghats as *Cryptorrhypops agharkarii*.

The Calcutta University was then vigorously growing under the influence of the late Sir Asutosh Mukerjee. At the instance of Dr. C. V. Raman, Professor Agharkar was invited to take up the newly instituted Ghosh Professorship in Botany in that University. Soon after, he proceeded to Germany for higher training in Plant Taxonomy and Plant Geography; but just after his arrival in that country, World War I broke out, and he was interned as an enemy subject in various camps in Germany, from October 1914 to July 1917. After his release, he worked under eminent botanists like Engler, Diels, Correns, Pilger, Lindau, Von Gutenberg and others and was awarded the Ph.D.

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\* Annandale, N., 1911, *Nature, Lond.* 87 (3).

degree of the Berlin University for submitting a thesis entitled *Verbreitungsmittel der Xerophyten und Sub-xerophyten des nordwestlichen Indiens und ihr Herkunft*. This thesis was deemed highly laudable by his examiners—Professors Engler and Haberlandt. This well-known thesis deals with the mechanism and means of dispersal of the xerophytes and sub-xerophytes of North-Western India and traces their origin and distribution. It was later published in the *Jahrb. System. Bot.* (56, Beibl. 124: 1-41, 1920).

He toured extensively in Denmark, Norway, France, Spain and Italy and made several excursions in the Pyrenees and Sierras Nevada as well as on the Mediterranean coast. He also worked for some time in the Herbarium at Kew. All the collections made during this period were presented by him to the Calcutta University and formed the nucleus of the Herbarium there. In July 1920 he resumed teaching at the Calcutta University. He explored the flora of Nepal visiting Gosainthan in 1921 and Muktinath, Damodarkund and valley of the Kaligandhaki in 1923.

Under his influence the Botany Department of the Calcutta University gradually expanded. A series of papers dealing with genera such as *Musa*, *Carica*, etc., and plants of economic importance such as jute and mango came out. The flora of North Bengal was also being intensively studied and schools of research in different branches such as Cytotaxonomy, Plant Geography, etc., were established. These schools are now being continued by such eminent workers as I. Banerji, P. N. Bhaduri, B. C. Kundu, K. Biswas, A. K. Ghosh, S. C. Sarkar, P. K. Sen, etc. In 1946 he retired from the Ghosh Chair and to commemorate his meritorious services to the University, a Gold Medal was instituted in his name. The phenomenal growth and development of the Botany Department of the Calcutta University which covers various distinct branches of the subject is a standing monument to his foresight and capacity for planning.

After his retirement from Calcutta he settled down at Poona. Here, with the help of eminent educationists in the city, he established, on 7th October 1944, an institution named as the 'Maharashtra Association for the Cultivation of Science' for the promotion of scientific research. This institution, which is under the auspices of the Indian Law Society, is actively engaged in research schemes on the Cytotaxonomy of Cereals, Plant Breeding, Mycology and Plant Pathology, Entomology, Microbiology, Plant Physiology, Palynology and Biochemistry. A unique feature of this institution is the team of retired scientists who actively participate in its research projects and guide young workers in various schemes sponsored by the State and Central Governments, Indian Council of Agricultural Research, the Council of Scientific and Industrial Research, etc. To his inspiration and guidance this institution owes all its achievements in the past two decades and it is to this institute that he has left all his property and assets including an excellent library full of rare books. Several young men who worked here have taken their Doctorate degrees in various branches. He was also closely

associated with the establishment of the Botany Department of the University of Poona and its subsequent growth.

Professor Agharkar was actively connected also with the growth and spread of scientific activity in India. He succeeded Dr. C. V. Raman as the Secretary of the Indian Science Congress Association from May 1924 to January 1935, and continued to be a member of its Executive Committee till 1946. In recognition of his services to this body, he was awarded the Indian Science Congress Medal and the Bruhl Medal by the Royal Asiatic Society of Bengal. In 1935, he was elected Foundation Fellow and Organising Secretary of the National Institute of Sciences of India and continued in this capacity till 1945. In 1938 he was appointed Secretary of the Soil Conservation and Afforestation Committee of the then National Planning Committee. The same year he also served as Chairman of a Committee for the creation of National Herbaria.

He was closely connected with the Indian Botanical Society right from its inception in various capacities, as President (1923), member of Editorial Board, and Honorary Treasurer and Business Manager. Professor Agharkar was connected with many other scientific bodies in the country. He has been the Honorary Secretary, Indian Society of Soil Science, 1935-40; President, Botanical Society of Bengal, 1940-45; President, Indian Ecological Society, 1940-45; Secretary, Biological Science, Royal Asiatic Society of Bengal, 1943-45; Vice-President, Royal Asiatic Society of Bengal, 1945-46; Vice-President, National Institute of Sciences, India, 1945-46, and served on the Indian Council of Agricultural Research, Indian Central Jute Committee, the Bengal Provincial Agricultural Research Committee and the Indian Research Fund Association, now the Indian Council of Medical Research.

He undertook, at the instance of the Bombay Government, a revision of the Botany volume of the *Bombay Gazetteer*. The first part dealing with medicinal plants was published in 1953 and the second part on timber and woody plants in 1957. He was actively engaged in the revision and preparation of the third part, dealing with the economic plants of the Bombay State, up to the time of his rather unexpected demise.

In spite of his failing health since 1956, Professor Agharkar maintained constant contact with the Maharashtra Association for the Cultivation of Science (M.A.C.S.), which was so dear to his heart, and other scientific activities. At the time of his sudden demise on the 9th September 1960, he was busy working, in collaboration with Shri A. K. Ghosh, Chief Palynologist to the Oil and Fuel Commission, on the floral elements of Bengal and the origin of the Bengal Flora. Even on the day prior to his demise, Professor Agharkar, against medical advice, had been to the M.A.C.S. laboratories and made kind enquiries about the workers there, as well as to the progress of the various research projects under way.

Professor Agharkar was a devout Hindu and a vegetarian throughout his life. He was deeply imbued with a strong sense of social obligations and nationalism. Quite a number of persons remember him with deep gratitude for his generosity, although like a true samaritan he never 'let his left hand know what his right did'. Professor Agharkar is survived by his wife. His students in Calcutta and elsewhere would long remember Mrs. and Professor Agharkar whose home was always 'Open House' to them. As was evident in all that he did, he had thoroughly imbibed the German tradition from his illustrious teacher, Professor A. von Engler, and to it he added the good in Indian tradition. In him Indian Botany has lost a stalwart who contributed in no small measure to the growth and spread of Botanical and all scientific knowledge in the country. May his soul rest in peace!

T. S. MAHABALÉ.



## REVIEWS

**The Orchids—A Scientific Survey.** Edited by Carl L. Withner, (*Chronica Botanica* No. 32. The Ronald Press Company, N.Y., U.S.A.), 1959. Royal 8 vo. pp. ix + 648. Price \$ 14.00.

In these days of specialisation, where progress is noticed in every branch of Botany, it appears to be quite fitting and opportune that a book on a fascinating and interesting group of plants, *viz.*, the Orchids, has been published by the Ronald Press Company, New York. The subject-matter has been treated admirably under the able editorship of Dr. Carl L. Withner, Associate Professor of Biology, Brooklyn College, Brooklyn. A fund of information is provided in this monumental work and in this great task the editor and the fifteen other specialists have collaborated in a very able way by contributing authoritative articles on various aspects of Orchidology.

There are 14 chapters with four appendices. In Chapter I, Carl L. Withner traces in a thorough manner the early history of orchids and their place in folklore. This is followed by Chapter 2 where Charles Schweinfurth has written in a very cogent manner the history of orchid taxonomy. The fine bibliography is very handy and it forms a useful reference to the general literature on orchids published from various regions of the world. In Appendix I, Schweinfurth has given a careful translation of Schlechter's key on the classification of orchids written in Latin. This 'long-awaited' key to the orchids in the English language is a boon to students and specialists in orchid taxonomy. He considers this classification as *par excellence* because (1) the key is strictly dichotomous, (2) emphasis is laid on reproductive structures and the more easily observed vegetative structures, and (3) it is the most recent and widely accepted scheme of classification, embracing a greater amount of material and a larger number of generic concepts than the other systems. It would have been more useful, however, if the translator had given the key to the further separation to genera under each subtribe.

In Chapter 3, Sam Shushan has given an account of the Developmental Anatomy of an Orchid, *Cattleya*  $\times$  *Trimos*. The developmental stages from seed to maturity are described. Mrs. Adams in Chapter 4 gives an excellent account of variation in orchids which is a very characteristic feature of Orchidaceae. The 61 illustrations which have been carefully chosen to demonstrate the variation in orchid flowers are particularly instructive. It is desirable that more drawings showing floral variation within a taxa are included.

Michael Wirth and Carl L. Withner in Chapter 5 have summarised the available information on the Embryology and Development in the Orchidaceae. These authors have pointed out that very little integration has been attempted to utilise this information as an aid to other fields of study, even though development and embryology are admirably



suiting to supply data for taxonomy and phylogenetics. The authors under the heading Apomixis on page 182 write "Polar bodies have not been known to develop into embryos in the Orchidaceae". This sentence is rather vague and not clear.

Chapter 6 is on Orchids and Cytology by Robert E. Duncan. The author has tried to cater to the needs of two types of readers: "One who knows little about orchids but a great deal about cytology and the other who knows a good deal about orchids but little about cytology" and in this endeavour he has certainly succeeded. This chapter together with the list of chromosome numbers appended in Appendix III should be invaluable both to orchid cytologists and breeders. The author has also indicated the vast scope for future work in this family since at present chromosome number is known only for 1-5% of the species. At one time the most common haploid number in orchids was supposed to be 16 but the present information indicates that 20 is the most common gametic number. Many errors have unfortunately crept in author citations and bibliography. On page 194, para 2, the name of Wilson (1949) is given but this is not cited in bibliography. Again on page 194, para 3, the work of Hagerup (1938) is cited, but in the bibliography two references are given (Hagerup, 1938 *a* and 1938 *b*); whereas in the body of the paper the author has not indicated whether he is referring to the first or second reference. On page 205 the name of Hoffmann (1931) is given but this is not cited in the bibliography. On page 229, para 3, the name of Löve (1954) is given but according to the bibliography it should be Löve and Löve (1954). It is suggested that these and few more errors of this sort are corrected in the next edition. For determining the chromosome number in orchids an account of the smear technique employed is given by Carl L. Withner in Appendix IV.

In Chapter 7 Lee W. Lenz and Donald E. Wimber have given a comprehensive review on Hybridisation and Inheritance in Orchids. Since the production of the first successful hybrid by John Dominy a little over a century ago, many thousands of hybrids have been produced, a record not equalled in any other group of plants. The chapter also includes a table on all multigeneric hybrids that have been evolved so far with the name of the originator. In spite of the innumerable hybrids that have been produced, the exact information on the genetic behaviour of the various species and hybrids are lacking. Even in this chapter there are a few errors in the bibliography.

Carl L. Withner has dealt in a very lucid and cogent way on the Physiology of Orchids. In this 8th Chapter the author lays emphasis on seed germination and reproductive physiology. The chapter also includes an extensive list of references. In Appendix III he has brought together very valuable information on culture media for orchids. Chapter 9, on Mycorrhiza of Orchids, is written in a fascinating and authoritative manner by H. Burgeff. Chapter 10, by Gavino B. Rotor, Jr., includes a concise review on Photoperiodism.

Chapter 11 on Fungal and Bacterial Diseases of Orchids by Peter A. Ark, Chapter 12 on Virus Diseases of Orchids by D. D. Jensen and



Chapter 13 on Orchid Pests and their Control by A. Earl Pritchard, are very comprehensive and these three chapters alone are worth the price of this book. A very well-written account on *Vanilla*—the orchid of Commerce—is presented in Chapter 14 by N.F. Childers, H. R. Cibes and E. Hernández-Medina. Information on the commercial production of *Vanilla* is also given.

The get-up of the book is excellent; the illustrations and photographs are very convincing. This fine book on orchids must have a place in all scientific institutions and universities.

K. SUBRAMANYAM.

**The Garden Flowers of China.** By H. L. Li. (Chronica Botanica—An International Biological and Agricultural Series No. 19. The Ronald Press Company, New York), 1959. Pp. vi + 240. Price \$ 6.50.

Many of the beautiful flowering plants as the peony, chrysanthemum, camellia, etc., introduced to the modern gardens the world over during the last two centuries have had their origin in China. The present-day collection of the innumerable, priced horticultural varieties of these and other species is actually the outcome of judicious selection, domestication and skilful development and improvement of ornamental plants by the Chinese people starting from the days of pre-history. In this fully illustrated book, the author has presented the story of gorgeous Chinese flowers and their association with the Chinese people throughout the past history. In the first chapter entitled 'China, Mother of Gardens', a general introduction is given about the unique vegetation of China, the geological and geographical factors that have been instrumental in assembling and preserving the richest and very diversified flora of all temperate regions, the art of Chinese flower culture, the beauty of Chinese favourite flowers and their symbolism. There is a fine chart on the origin of important garden flowers in China. In the second chapter, the author has reviewed Chinese horticultural literature both ancient some dating back to ninth century B.C. and modern. In Chapters 3 to 23 are found detailed and interesting accounts of moutan peony, the herbaceous peony, the chrysanthemum, the Japanese apricot, the peach blossom, the sacred lotus, orchids, camellias, *Narcissus*, the roses, the mysterious jade flower, day lilies, lilies, crab apples, jasmine, *Viburnum* and *Hydrangea*, *Hibiscus*, *Magnolia*, *Azalea*, *Begonia* and *Wisteria* respectively. In the last two chapters, exotic flowers and recent introductions are described. The book includes scientific names for each species, brief botanical descriptions and detailed bibliographies of the Chinese literature. Together with scientifically established facts, the author also covers the legendary material, translations of Chinese names, their symbolism, their uses in the gardens and homes of China and also how they were introduced into the Western world. Besides the literature pertaining to specific plant groups listed at the end of the chapters, there is a general bibliography and a bibliography of Chinese horticultural writings published before 1850.



The book is very well written and is attractively got up. The illustrations are excellent and most of them are copies of Chinese originals as much as 850 years old. The book has 18 delightful Plates which are reproductions of paintings of important flowers in colour on silk, in ink on paper and on Chinaware, of the early Chinese dynasties. This book will be of much interest to botanists, orientalists and horticulturists and it should find a place in all botany libraries.

C. B. SULOCHANA.

**Beautiful Climbers of India.** By Dr. B. P. Pal. (Published by the Indian Council of Agricultural Research, New Delhi, with a Foreword by Dr. M. S. Randhawa), 1960. Pp. 105. Plates 39. Price Rs. 8-00.

Every lover of nature will welcome this book. The author is a well-known naturalist with a fervour. The book embodies his experiences as well with the climbers and is of very great value.

The first chapter deals with the classification of the climbers and in the second chapter, "How to Grow Them" and in the table on pages 98-100, the author has set forth the general lines of guidance for the cultivation and selection of one's favourites from among those dealt with in the book. Nearly a 100 species of the more common climbers of India are dealt with in the book and of these nearly half of them at great depth. For each of the latter are given a brief description, in very simple language, of the plant, its horticultural varieties, details of flowering, propagation, etc., informations which will be of great help to gardeners and selectors. Notes given by the author on the selection of those climbers in keeping with the architectural background of the building will prove a great help in the decoration of private and public buildings.

The book is very neatly and well illustrated with 39 colour plates. These include some beautiful paintings by Ganga Singh, while the rest are colour photographs and all of them bring out the prominent features of the climbers to enable even the lay-reader to identify common climbers.

The layout of the book and the cover design are artistic and the printing of the book has been neat and of a high standard. The Author and the Indian Council of Agricultural Research are to be congratulated for this publication. Such publications will, it is hoped, if followed by books on local flora similarly designed, are bound to be of great interest to naturalists and will be useful to gardeners, ornamentalists, plant hunters and will enthuse many lay-people into a keener search for plants yet unknown.

T. V. DESIKACHARY.